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The ***International Journal of Food Studies (IJFS)***, a journal of the ISEKI_Food Association, is an international peer-reviewed open-access journal featuring scientific articles on the world of Food in Education, Research and Industry. This journal is a forum created specifically to **improve the dissemination of Food Science and Technology knowledge between Education, Research and Industry** stakeholders. Core topics range from raw materials, through food processing, including its effect on the environment, to food safety, nutrition and consumer acceptance. To enrich this forum the journal is also open to other food-related topics such as food policy and food anthropology.

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Assessment and Evaluation of Emergency Remote Teaching for a Project-Based Assignment on the Production of Eco-Innovative Food Products – A Case Study

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Abstract

Institutions of Higher Education (HEIs) faced great challenges, due to the COVID- crisis, on swiftly dealing with this unprecedented situation regarding the implementation of practical courses and interactive educational activities such as project-based courses. The aim of this work is to analyze the challenges and difficulties that arose through this process and the benefits that have emerged for both students and educators. For this reason, questionnaires were designed to study the pedagogical practices used for a project-based course, during the pandemic, and were distributed online to all students and supervisors enrolled in the course. The course entailed the design of an innovative food product, from the interactive analysis of different novel ideas to the production of a final product of high nutritional and ecological profile. Despite the concern that the enforcement of distance learning would significantly affect project-based courses, the majority of respondents confirmed that their institution adapted the curriculum successfully. They also declared satisfaction with the general format, and teaching procedures adopted, and agreed that the online modality can properly transmit educational content. Although, both faculty and students needed to adapt to the distance learning modality and become familiar with the use of new digital tools, they agreed that it can be very useful and provide benefits, when properly planned in advance and accompanied by the right technical support, equipment and class materials.

Keywords: Project-based courses; Distance learning; COVID-19 pandemic; Digital tools; Ecotrophelia contest

1 Introduction

In March 2020, the Director General of the World Health Organization (WHO) declared COVID-19 as a pandemic, after the assessment of the rapid spread and severity of the SARS-CoV-2 virus across the globe, and additionally announced social distancing as a means of containing its spread (World Health Organization, 2020). This worldwide health crisis forced the physical closure of businesses, sport activities and schools globally and pushed all institutions to migrate to online platforms. The online learning modality was seen by the United Nations (UN) and the WHO as a helpful tool for meeting educational needs during the pandemic. Higher Education Institutions (HEIs) have implemented numerous creative strategies to combat the crisis, using various software/apps such as Google Classroom, Zoom, Cisco Webex, Microsoft Teams and others, in order not only to

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continue and complete the educational process but also to stay in constant contact with their students (Zalat et al., 2021).

The COVID-19 pandemic globally initiated the digital transformation of higher education within a limited number of days, which would take years, under normal circumstances, due to managerial regulations. Although the digital transformation of education is not a novel phenomenon, and some HEIs had adopted online learning over the past two decades, it was never considered as part of the formal education in undergraduate students in most countries, including Greece. And that's because there are five main common hurdles to the realization of the digital transformation of HEIs, namely change, financing, technology, pace and competencies (Adedoyin & Soykan, 2020). Thus, even though, the current health crisis led the entire world to rely on the online learning modality, the education offered should preferably be referred to as "emergency remote teaching" in contrast to quality or effective online learning (Iglesias-Pradas et al., 2021). Indeed, online education, when carefully designed based on the available theories and models, can be a student-centered, creative and flexible platform (Alhawsawi & Jawhar, 2021; Rahman et al., 2015). A truly beneficial remote learning course should look attractive, encourage participation, incorporate various activities and learning styles that support the learning objectives, and combine elements of asynchronous and synchronous learning to maximize students' engagement, while maintaining the core course's objectives and goals (Schreck et al., 2020).

Additionally, food science and engineering study programs have undergone, during the last years, a paradigm shift from the delivery of knowledge in a traditional lecture and laboratory system to a more inquiry-based and discovery process. Traditional laboratory practices often leave little room for creativity or contextualization (Flynn et al., 2017; Giannou et al., 2015). Innovations, such as the use of team-based learning, simulations or problem-based studies engage students more actively in the learning process. This educational approach, based on an integrated multidisciplinarity, allows graduates to enter the job market with the appropriate technical skills and knowledge, including food quality and safety, food analysis, processing and engineering. This shift emerged from the observation that students lacked practical competence at the beginning of their career, because they had limited or no exposure to practical experiences (Fonseca et al., 2015; Giannou et al., 2015). It was suggested that students need a way to put their classroom knowledge into practice and enhance their mastery of the curriculum, thus improving their preparation for employment in the field (Burke & Danaher, 2020; Flynn et al., 2017; Schreck et al., 2020). Project-based learning uses instructional strategies that are intended to engage students in authentic, "real world" tasks to enhance learning. It can be an individual or group activity that goes on over a period of time, resulting in a product, presentation or performance. Project-based learning typically has a timeline and milestones, and other aspects of formative evaluation as the project proceeds. Students engage in deeper learning and high-level reading, and their motivation is increased. Studies carried out in the United States of America and United Kingdom showed that students who enrolled on project-based assignments were superior in answering applied and conceptual problems (Gutierrez-Bucheli et al., 2022).

However, the emergency remote teaching methods adopted by universities during the pandemic were limited to delivery media, without taking full cognizance of these practices. Administrators and educators tried to effectively deliver remote teaching via e-lectures, e-tutorials, e-project-based learning, etc., to ceaselessly continue education during the quarantine period. The imposition of emergency remote teaching on all HEIs' courses forced the educators to decide abruptly which education modality and strategy to adopt; in this case, instructors had to rush to choose among multiple digital tools with different capabilities to support teaching. More particularly, some of these decisions included the support of asynchronous (content management systems, message boards, e-mail, pre-recorded videos of class sessions), or synchronous (chat, videoconferencing) or real-time collaboration systems (instant messaging/tools) and may have even involved changes in the assessment activities or assessment criteria. Nevertheless, the transition from traditional face-to-

face teaching to remote teaching is not a seamless task, particularly when educators do not have enough time to adapt and adjust their pedagogical assumptions. Such challenges can be more intense if the changes are suddenly introduced, as in the case of the COVID-19 pandemic. While enhancing technological literacy seems to be more easily achievable, changing teaching and learning assumptions might be the real challenge. This transition includes redefining the educators' roles, and rethinking how they interact with their students and how their students interact with each other in the new online environment. Nevertheless, the lack of resources, time, training and experience can be a burden during this transformation.

The compatibility of online learning with social sciences and humanities has proved effective in contrast with sports science, engineering and medical sciences where hands-on practical experiences are required as part of the instructional activities. Consequently, technological institutes of higher education faced great challenges on how to swiftly deal with this unprecedented situation regarding the implementation of practical courses and interactive educational activities such as project-based courses (Khan & Abdou, 2021). Where possible, virtual laboratories were commonly provided through online learning. However, these can only partly address theory into practice (Koulouris et al., 2015), with a substantial compatibility gap still waiting to be filled (Abumalloh et al., 2021).

This study accumulates information on project-based courses delivered online in the School of Chemical Engineering of the National Technical University of Athens (NTUA) and presents the difficulties that both educators and students have experienced during the abrupt shift from face-to-face classes to distance learning education, since the university had no previous experience with online learning before COVID-19. It also tries to decipher if the complexity of the structure of these project-based courses has been negatively affected by the COVID-19 crisis. In order to evaluate the changes imposed in the educational process, it is now necessary to record and analyze the experiences and opinions of all those involved in the virtual approach of teaching and learning, their possible suggestions for its improvement as well as their preference towards going back to conventional learning. Finally, this study investigates the impact of such choices on academic performance so as to identify successful transitioning strategies.

With these issues under consideration, this study addresses the following questions:

- What were the challenges and obstacles of emergency remote learning during the COVID-19 crisis encountered by both educators and students during the project-based courses?
- How have instructors adapted their teaching of graduate courses to emergency remote teaching during the COVID-19 pandemic?
- Which were the best methods and modes to engage and motivate the students?
- Did the students obtain an effective and complete education on the project-based courses?
- Did the use of educational platforms and tools improve educators' competency necessary for online education?
- Did the familiarization of educators and students with the currently used platforms, tools and applications assist in enhancing and reinforcing education during the digital transformation?

2 Materials and Methods

2.1 The class

The class consisted of 43 undergraduate students, in the 4^{th} year of the 5-years curriculum of the School of Chemical Engineering (NTUA), withing the course "Chemistry, Microbiology and Food Preservation Principles" organized by the Laboratory of Food Chemistry and Technology (FOOD LAB). The class was sub-divided into "project groups" with 5–6 members per group.

2.2 Curriculum

The module ran for 8 weeks during the spring semester (February-June) of the academic year 2020-2021. The main features of this module were theoretical lectures and practical laboratory exercises delivered online, and a project-based assignment that was conducted during the semester. The theoretical lectures and laboratory exercises of the curriculum cover the study of food ingredients, their physicochemical, biological and functional properties, their chemical and microbiological effects, their quality and safety, their alterations and their behavior under the range of conditions encountered during processing, packaging and preservation of food products.

The project-based assignment concerned the design of an innovative food product, from the interactive analysis of different novel ideas to the production of a final product. The basic idea for its design is based on the "ECOTROPHELIA" competition - a food innovation competition for higher education students to develop eco-innovative food products. This competition, which is widely known to agri-food HEIs, is fostering creativity and entrepreneurship European-wide, and reshaping the future of food by bringing together HEIs and the agri-food industry. The FOOD LAB has actively participated in the ECOTROPHELIA competition since 2011 and has won numerous awards, both in the national and international competition.

The experience gained from the ECOTROPHELIA competition and the implementation of the project-based assignment also resulted in the participation of the FOOD LAB in the European "DigiFoodEdu" project. It is a project funded by Erasmus+ which aims to foster the development of digital skills and exchange of good pedagogical practices in the digital era directed at the guidance of project-based learning approaches. Its main scope is to study the pedagogical practices put in place during the pandemic, collect and analyze the experiences from different partners European-wide and come up with a best-practice guide for the improvement of education in the digital era. Ultimately, the project aims to modernize the pedagogical practices used for coaching and supporting students during their project-based learning activities. The data presented in this study were collected within the framework of the "DigiFoodEdu" project and are specific (spring semester, 2021) to the project-based assignment in the FOOD LAB.

The project-based assignment was delivered by a teaching team consisting of 13 members, including teaching professors, laboratory and teaching staff and PhD students, and was supported with digital contact sessions (45 min - 1 h per week). The basic scheme followed during this procedure is described in Figure 1.

More specifically, students were asked to gather information and design their model food product based on a certain food category, namely bakery products, snacks, dairy products, frozen products, gluten-free products, meat products, alternative meat products or products containing functional ingredients from natural sources. Their final report - the product's technical folder - should include information on product's formulation, processing technology, packaging, distribution requirements, carbon footprint, conformity with National Safety Authority laws and European Food Regulations, as well as marketing and feasibility plans. By the end of the course, students were asked to deliver this technical folder and prepare a 15 min presentation of the product along with an advertising leaflet.

Context

The main focus of the module was to provide students with an opportunity to integrate all their previous academic experience in food science, technology and engineering within a single project by practically exploiting the skills and knowledge gained through their studies. The module focused specifically on the understanding of the key concepts and processes; scientific ability to seek and evaluate information, communicate in an accurate and coherent way, act as a group member and successfully complete the project. As a group, they were in control of an entire project, from planning to implementation and evaluation, with each member taking responsibility for his or her part within the project. Nearly half of the contact sessions were spent focusing on theory, the application thereof and

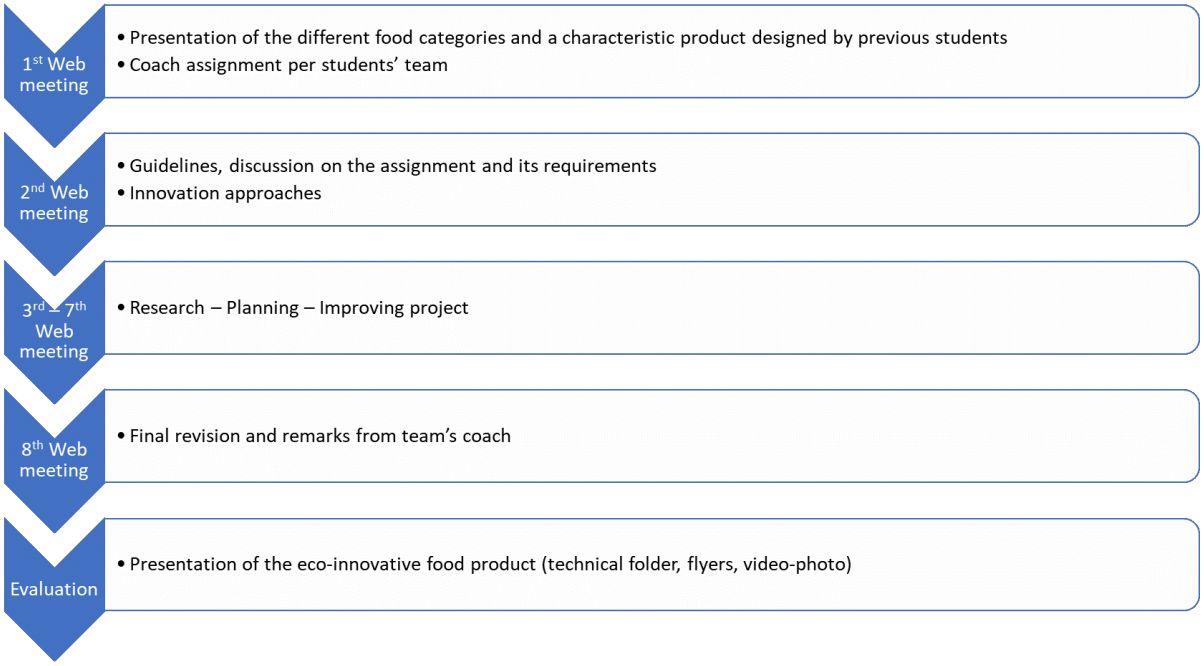


Figure 1: Stages in the project-based learning assignment.

project planning. The other half was spent in presenting the implementation of their projects.

Total energy

Direct assessment

Summative assessment is product-oriented and assesses the final product, technical folder and final presentation, whereas formative assessment focuses on the process toward completing the project assignment. Both were used to assess the students as described below.

Summative

Final report (technical folder): The final report accounted for 100% of the total grade of the module. The technical folder consisted of the following sections: (1) Introduction, (2) Food category definition – Food legislation, (3) Raw materials – Technical characteristics of the product (composition, manufacturing flow chart), (4) Innovation characteristics – Environmental impact, (5) Business and marketing plan, (6) Technical feasibility at an industrial scale and (7) References. The outcome of the module is considered successful when students' final grade is above 5 on a 10-point grading scale, and along with the other laboratory exercises, accounts for 50% of the final grade of the course.

Formative

Informal observation: The teaching team was able to observe each individual student's approach during the planning and development of the project assignment over the 8 weeks of the remote classes.

Indirect assessment

Questionnaire

Upon completion of the course, students were asked to answer a series of questions on the distance project-based course they attended. The initial questions were more general and related to the evaluation of students' overall experience

from distance learning courses. The following questions were more detailed, so that participants' opinions and observations could be outlined. The questions were closed-ended and could be answered with a yes or no, by choosing between a list of possible answers or by choosing between a scale (e.g., strongly agree to strongly disagree). There was also an open-ended question that concerned the difficulties and problems of presentation in a distance learning course. A corresponding questionnaire was designed to capture the experience of the teaching staff as well. The questionnaires developed were jointly evaluated and approved by the group of experts/educators participating in the "DigiFood-Edu" project and were then distributed online to the 43 bachelor students and the 13 course supervisors enrolled in the course. The structure of the questionnaires is presented in Table 1.

3 Results and Discussion

3.1 Profile of the respondents

During the survey, 50 questionnaires were filled in completely or partly; 13 from professors and pedagogical staff and 37 from students (86% response rate). Considering the distribution of gender, females dominated the population size (62% female professors versus 38% male, and 70% female students versus 27% male). Regarding age, teaching experience and rank of the supervisors' project group, they were divided as follows: ages below 30 (31%), between 31-50 (61%) and above 51 (8%), teaching experience of less than 5 years (39%), 6 to 10 years (38%), 11 to 20 years (15%) and above 20 years (8%). 15% of the respondents were professors, 19% were research associates and only 8% were PhD students-researchers. Considering the students' project group, 78% were between 19 and 23 years of age and 22% between 24 and 29 years (Table 2).

3.2 Distance learning modality offered by Higher Education Institutions before and during the COVID-19 pandemic

Regarding the experience of distance learning prior to the COVID-19 pandemic, the majority of professors (85%) answered that they were not familiar with distance learning (Fig. 2a) and all the respondents answered that they used remote lectures only for theoretical sessions (Fig. 2b). Moreover, at the beginning of the COVID-19 era, 61% of the pedagogical staff stated that they had no experience with distance learning, while 31% that it was their first experience with the online teaching modality (Fig. 2c). Prior to the COVID-19 outbreak, the majority of supervisors preferred the presential synchronous learning modality (face-to-face classes on campus) (84%), and only 8% used distance synchronous learning (online live courses that are interactive between teacher and students in real-time) (Fig. 2c). Despite the limited experience of supervisors with distance learning, 46% of them believed that they were technically prepared for remote teaching or expressed a neutral opinion (23%) (Fig. 2e). Overall, they were accustomed to the use of technology and digital tools, as 71% of them were very confident when it comes to working with technology at home or at university and they did not avoid using technology when necessary to offer feedback on students' assignments. Moreover, the majority of supervisors stated that they enjoyed using digital tools (53% strongly agreed and 35% agreed), while 35% of the respondents strongly disagreed, 6% disagreed and 29% expressed a neutral opinion on the statement that digital pedagogical tools hinder the educational process (Fig. 3a). The results emphasize that even though the distance learning modality was not common before COVID-19, the respondents were confident that they will carry out remote teaching successfully as most of them were familiar with the use of technology and digital tools in the educational process. However, in other studies, different results were observed as before the pandemic, the educators did not understand the importance of having advanced or even novice technology skills or online plat-

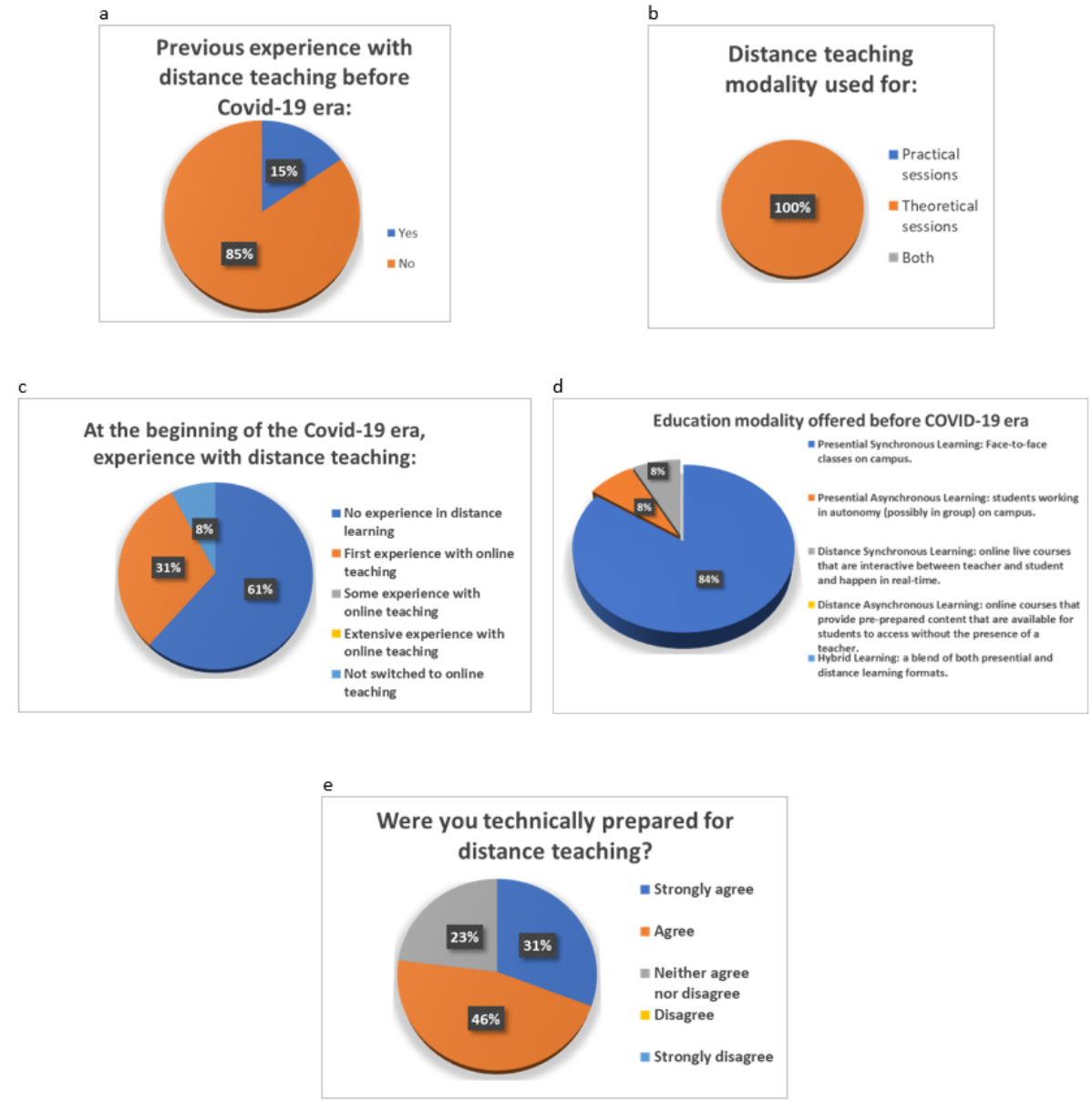
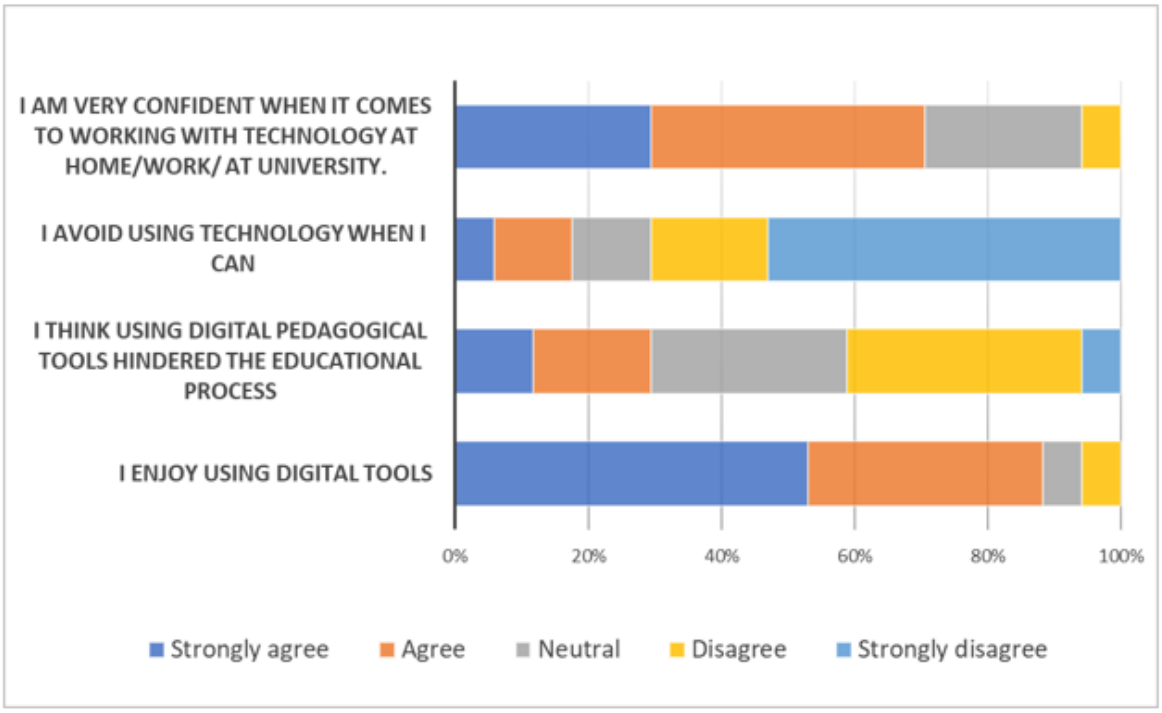


Figure 2: (a-e) Professors' and pedagogical staff's responses regarding the education modality before COVID-19 pandemic.

a



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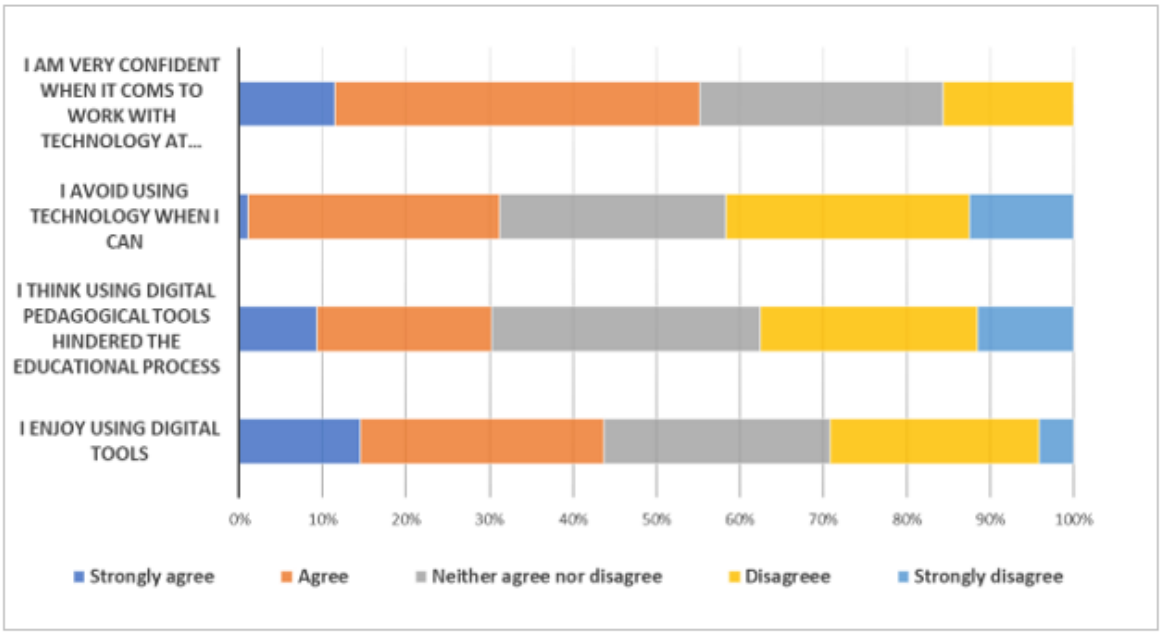

Figure 3: (a) Professors' and pedagogical staff's and (b) students' responses, regarding the use of technology and digital tools in education.

Table 1: Dimensions of the questionnaires' structure

Questionnaire structure	
Students	
Section 1 Digital pedagogical practices during the COVID-19 era for project-based distance learning course	· Experience with distance teaching before and after COVID-19 · Digital tools and supplementary materials used in project-based e-learning · Validation of the digital tools used and the overall teaching experience · Familiarity with ECOTROPHELIA competitions · Familiarity with project-based e-learning · Information on project-based e-learning · Validation of the digital tools used and the overall learning experience · Comparison of the online experience with traditional face-to-face courses · Difficulties/problems encountered from distance learning · Suggestions for the improvement of the online experience
Section 2 Student-Teacher dynamic and communication during distance courses	· Effect of distance learning on student-teacher relationship · Validation of students-teachers interaction/communication during project-based e-learning courses · Validation of the online learning experience · Contribution of project-based courses to students' future career
Section 3 Attitudes to technology	· Equipment used in distance learning courses · Problems with internet connection and experience from the use of digital tools · Evaluation of the impact of distance teaching in future school practices
Section 4 Information of the respondent	· Demographic data · Information on respondents' status and grade
Teachers	
Section 1 Digital pedagogical practices during the COVID-19 era for project-based distance learning course	· Type of education modality offered before COVID-19 · Experience with distance teaching before and after COVID-19 · Familiarity with ECOTROPHELIA competitions · Familiarity with project-based e-learning · Supplementary materials used for distance learning · Technical preparation for distance teaching · Digital tools used in project-based e-learning · Validation of the digital tools used and the overall teaching experience · Comparison of the online experience with traditional face-to-face teaching · Difficulties/problems encountered from distance learning · Suggestions for the improvement of the online experience · Evaluation of the technical skills acquired from distance teaching
Section 2 Student-Teacher dynamic during distance courses	· Rating of the involvement of students in the project-based e-learning courses · Validation of students-teachers interaction/collaboration/ communication during project-based e-learning courses · Degree of difficulty to switch to the e-learning courses · Use of technology and online tools/sources to improve the learning process and offer feedback on students' assignments · Contribution of project-based courses to students' future career
Section 3 Attitudes to technology	· Equipment used in distance learning courses · Problems with internet connection and experience from the use of digital tools · Evaluation of the impact of distance learning in future school practices
Section 4 Information of the respondent	· Demographic data · Teaching experience · Information on respondents' status and position

Table 2: Socio-demographic data of the studied class

Professors & Pedagogical Staff (Total answers: 13)			
Gender:		**Rank:**	
Female	62%	PhD candidates -researchers	8%
Male	38%	Research Associates	19%
Prefer not to say	-	Professors	15%
Age:		**Teaching experience:**	
<30	31%	<5 years	39%
31-50	61%	6-10 years	38%
>51	8%	11-20 years	15%
		>20 years	8%
Students (Total answers: 37)			
Gender:		**Age:**	
Female	70%	19-23	78%
Male	27%	24-29	22%
Prefer not to say	3%		

forms knowledge and relied only on their ability to interact face-to-face with students in the classrooms (Alhawsawi & Jawhar, 2021; Rasheed et al., 2020).

Similar results were observed from students' responses as they were very confident when it comes to working with technology (11% strongly agreed and 44% agreed with the statement). Moreover, when they were asked if they avoided the use of technology whenever possible, responses were divided amongst three options: 30% agreed, 29% disagreed and 27% neither agreed nor disagreed. The students gave similar answers to the question "if they enjoy the use of digital skills": 29% agreed, 25% disagreed and 27% neither agreed nor disagreed. However, regarding the question "if the use of digital pedagogical tools hinders the educational process", interestingly 30% of the students agreed, whereas 29% disagreed with this statement and 27% of them had a neutral opinion (Fig. 3b). Others studies, similarly confirmed that high educational competence skills help educators pedagogically and increase the level of students learning (Núñez-Canal et al., 2022; Reisoğlu & Çebi, 2020).

The situation changed drastically as the COVID-19 pandemic led to massive closures of HEIs and many countries took measures to limit the disruption to education, necessitating a move to online and distance learning. 92% of respondents stated that their HEI turned to distance education using a Learning Management System (LMS), Video Conferencing (VC) platforms or learning materials and tools available on the internet. 77% of the educators confirmed that their institution provided them with supplementary materials for distance learning (online libraries subscriptions, digital tools, premium user accounts to e-learning platforms) (Fig. 4a). Also, it was also very encouraging that students had access to supplementary materials for distance learning, thereby facilitating the lectures, and 57% of students had subscriptions to online libraries or were premium users of an LMS or VC platform. Cisco Webex, Google Meet, Microsoft Teams and Zoom were the most widely VC platforms used, whereas, Google classroom, Moodle, Blackboard, Discord, BigBlueButton and Jamboard were the LMS platforms and other digital tools used to different extents (Fig. 4b). The results showed that a large variety of digital educational tools was available for educators to cover the needs of their students during the distance learning/education process. It was also observed that the instructors seemed to resort to digital tools that they were most familiar with, and with instructional methods that most

easily resembled the face-to-face learning practices (Iglesias-Pradas et al., 2021). Moreover, it should be highlighted that the younger educators were keener to use digital tools and LMS or VC platforms. However, after more than a year, the situation was very different as the majority of educators (54%) stated, at that stage, that they had some (54%) or extensive experience (38%) with online teaching (Fig. 4c).
Similarly, the majority of students stated, at the beginning of the COVID-19 era, that they first came into contact with distance learning (16%) or had no experience with it (59%), while only 14% of the respondents had some experience with online learning (Fig. 4d). However, a year after the COVID-19 outbreak, the students were confident enough to state that they had gained extensive (60%) or some experience (32%) with distance learning. Only an inconsiderable percent of 3% expressed that after one year of online learning modality they were still not familiar with distance learning (Fig. 4e).
Considering the question "if they encountered problems during online lectures", 59% of the educators answered affirmative, stating that the poor internet connection hindered the educational process. The outcome was the same for students, as 62% of the respondents stated that the poor internet connection hindered their attendance at lectures. Regarding the equipment used, 77% of the educators answered that they used a personal computer to attend the lecture, or several devices (23%) depending on the sessions. Similar results were observed for students as 68% of them attended the lectures using their personal computer, 24% of them used several devices alternatively depending on the sessions and only 8% of the students used several devices simultaneously (Fig. 5).

3.3 Readiness of Educational Institutions to continue the project-based courses during the distance learning era

The enforcement of distance learning significantly affected the project-based courses and the relevant educational competitions for higher education students. The impact of the pandemic became particularly noticeable to the participants of the "ECOTROPHELIA" competitions. Following the transformation of education and educational activities, the national and European ECOTROPHELIA competitions reinvented themselves to continue to provide students and HEIs a platform to showcase their talents during the COVID-19 pandemic. In the 2020 the competition took place virtually, and the majority of students and educators were very well informed about the change, as 65% of the students and all the educators (100%) confirmed that they were aware of the new form of the competition (Fig. 6).
The results of the survey confirmed the significance of the incorporation of such project-based courses in the curriculum, as 46% of the educators strongly agreed and 31% of them agreed that the project-based courses prepare and support the students for a future career (Fig. 7a). However, the opinion of students regarding the significance of project-based courses was divided (35% of them agreed and 33% neither agreed nor disagreed) (Fig. 7b). These results support claims made in the literature that an experiential learning approach can improve the graduate attributes needed by students, making them more employable (Schreck et al., 2020).
Inspired by the "ECOTROPHELIA" competition, the students enrolled in the course "Chemistry, Microbiology and Food Preservation Principles" were assigned a project-based course, where they were motivated and coached by an educator to develop their eco-innovative food products virtually. At the same time, the educators faced similar difficulties and new challenges, as 23% of the supervisors and 43% of the students confirmed that the transformation of the project-based learning courses into an online modality was difficult (Fig. 8a, b). However, the majority of educators (54%) expressed a neutral opinion regarding the difficulties of transformation of project-based courses in the distance learning modality.
During the lectures for the project-based distance courses, the educators stated that they used various dynamic teaching techniques, such as live deductions, writing on a virtual board, video projections, online quizzes, online workbooks, etc., to engage and motivate their stu-

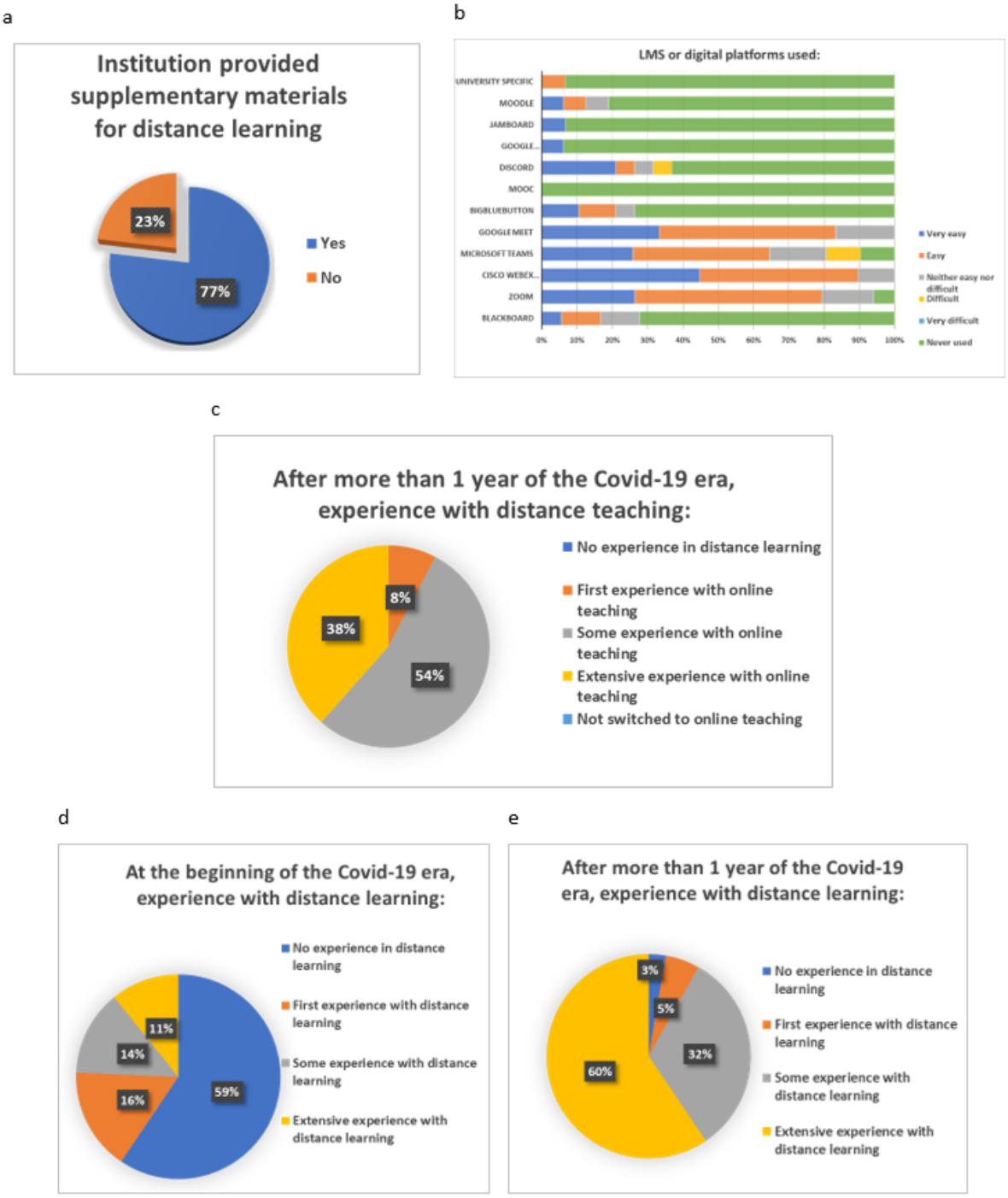

Figure 4: (a-c) Professors' and pedagogical staff's responses regarding the teaching experience during the COVID-19 pandemic. (d-e) Students' responses regarding the teaching experience during the COVID-19 pandemic.

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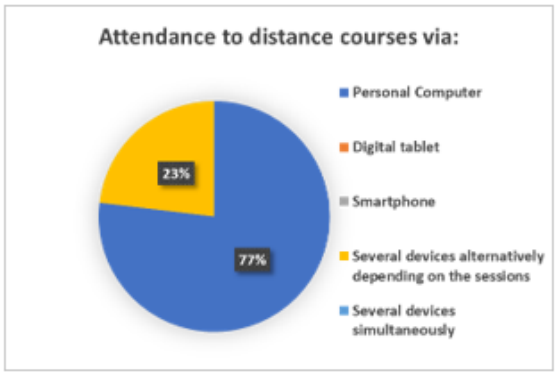

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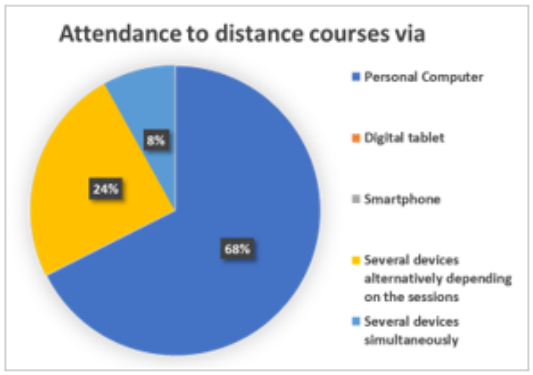

Figure 5: (a) Professors' and pedagogical staff's and (b) students' responses regarding the use of devices for their attendance on the distance learning courses.

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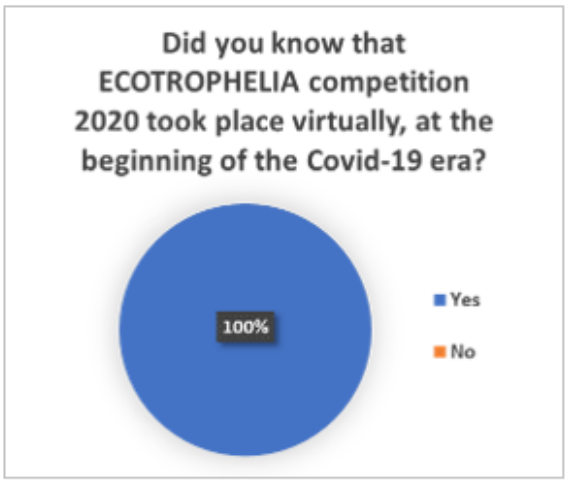

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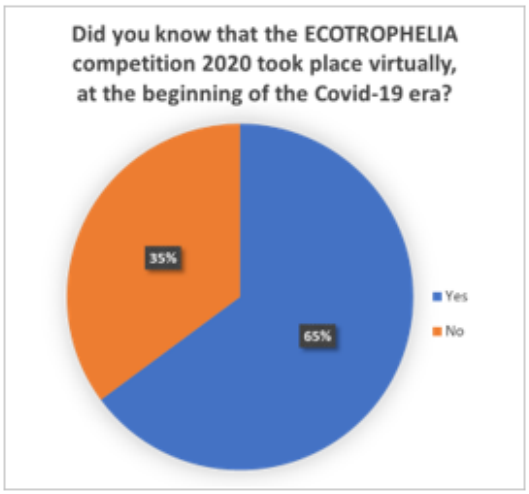


Figure 6: (a) Professors' and pedagogical staff's, and (b) students' responses regarding the virtual conduct of the ECOTROPHELIA competion in 2020.

dents (Fig. 9).
Also, the majority of educators agreed with the statement that the digital tools used were appropriate for the project-based e-learning courses (23% strongly agreed and 46% agreed) (Fig. 10a). As in can been seen in Figure 10b, educators seem to resort to digital tools that they are most familiar with and use instructional methods that most easily resemble their current practices, such as synchronous sessions that mimic face-to-face learning.
Overall, the instructors were satisfied with the teaching procedures adopted for project-based distance learning courses, believing that their methods were suitable for the course's objective, as 35% of them strongly agreed and 53% of them agreed with the statement (Fig. 11). Also, 18% of them were strongly satisfied and 41% were satisfied with the general format of online teaching (the teaching procedure, the selected digital tools, the number of students, the teaching hours), while 41% of them were neutral regarding this matter. Considering the asynchronous modality used, the answers were divided as 41% of the instructors agreed with the statement that the asynchronous modality can transmit the educational content properly and 41% of them had a neutral opinion (Fig. 11). Other studies also indicated the importance of using effective technological tools and emphasized the role of information sharing and collaborative actions on a project-based course (Abumalloh et al., 2021; Adedoyin & Soykan, 2020).
Moreover, 12% of the educators strongly agreed and 35% of them agreed that the quality of education offered through distance learning was good enough. Unfortunately, 47% of the respondents were skeptical about it. Despite the optimistic results of the modality and the quality of distance learning, unfortunately, 41% of the educators believed that they were not motivated enough to teach a class through remote teaching or expressed a neutral opinion (41%), and only 6% were more motivated to do so (Fig. 11). Moreover, 24% of the respondents strongly agreed and 59% agreed with the statement that more effort was needed to complete a discipline in the distance learning modality than in the face-to-face modality (Fig. 11).
From the students' perspective, they also agreed (51%) that the distance learning class material for project-based courses was useful and accurate, and 32% strongly agreed. Moreover, 49% of the students agreed and 27% strongly agreed that the procedures adopted by professors and pedagogical staff were suitable for the course's objective. The majority of students believed that the digital tools used were appropriate for project-based e-learning courses (43% agreed and 16% strongly agreed) (Fig. 12) and were also appropriately used (87%). Moreover, they believed that their professors were technically prepared to deliver a project-based e-learning course (59% agreed, 16% strongly agreed and 30% expressed a neutral opinion). Therefore, teachers who have the appropriate technical skills for synchronous teaching, are more ready to adopt and diversify their teaching approaches in order to deal with unforeseen circumstances in education such as the COVID-19 outbreak (Alexander et al., 2017; Alhawsawi, 2017; Alhawsawi & Jawhar, 2021).
Although, both educators and students were satisfied with the distance learning modality of project-based e-learning courses, the majority of educators think that the final presentation of the assigned project-based course was challenging (54%) or very challenging (8%). The results highlighted that the educators were not very satisfied with the final presentation of the students as they probably detected that the students were more anxious or less prepared as speakers and unfamiliar with the online presentation modality. However, the students had a different opinion as they found the procedure in the distance learning modality as difficult as in the traditional presentation (35% of them found the online presentation challenging, while 30% of students found the procedure easy) (Fig. 13). These results indicated that even though it was easy for the students to attend asynchronous classes, some students faced difficulties presenting online to their classmates. During the final presentation various education platforms were used, with Zoom, Cisco Webex and Microsoft teams being the most popular and user-friendly according to the respondents.

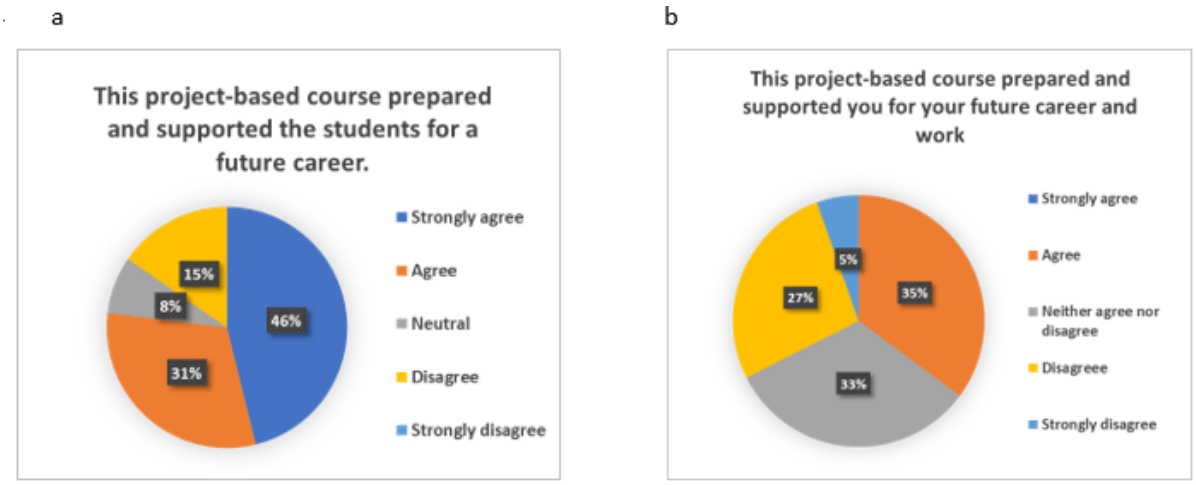


Figure 7: (a) Professors' and pedagogical staff's, and (b) students' responses regarding the importance of project-based courses.

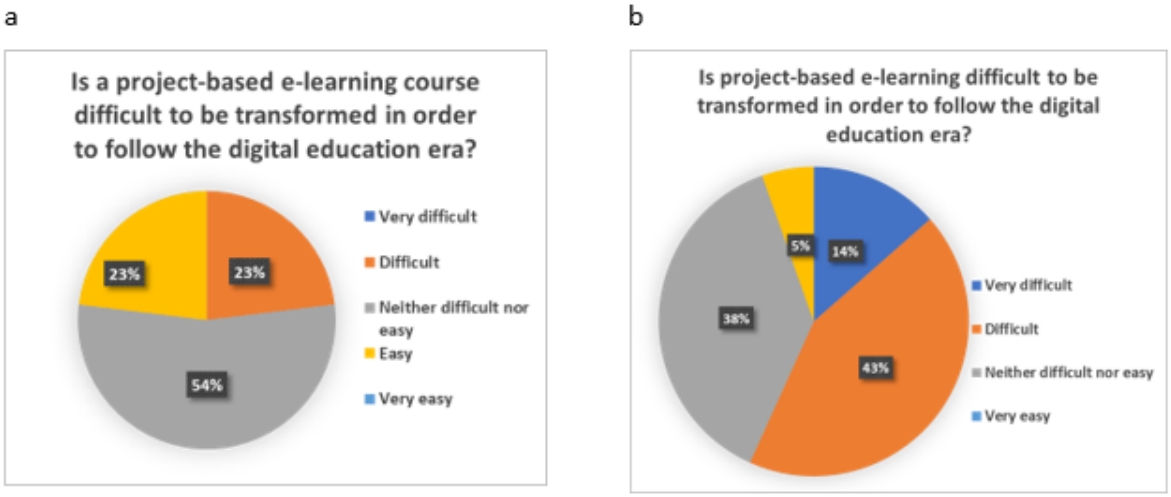


Figure 8: (a) Professors' and pedagogical staff's, and (b) students' responses, regarding the transformation of project-based distance learning courses.

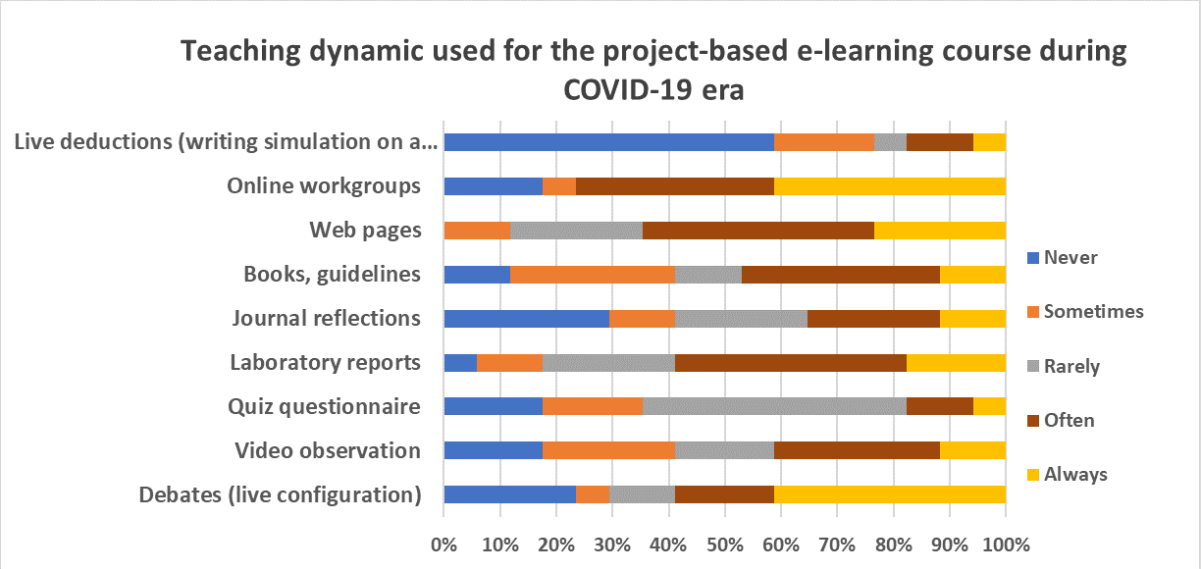


Figure 9: Dynamic teaching techniques used by professors and pedagogical staff during the lectures on the project-based courses.

3.4 Student-Teacher dynamic during the project-based distance courses

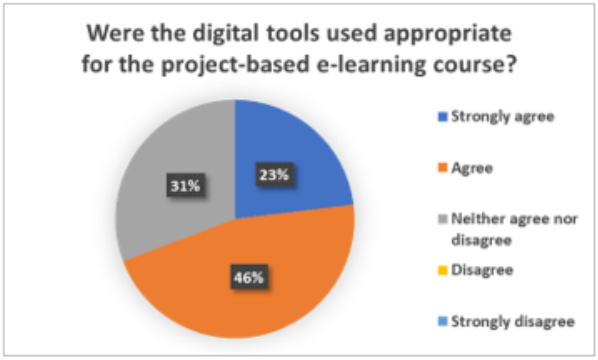
Another important factor that should be studied due to the imposition of emergency distance learning is the relationship and communication among students and educators, and students' participation during the online lectures. The ability to ask a question, to share an opinion or to disagree on a topic are all key learning activities (Rahman et al., 2015).

Some studies observed that the digital environment can result in a poor learning experience for students (Ghomi & Redecker, 2019; Núñez-Canal et al., 2022). Therefore, it was expected that the teacher-student relationship would be negatively affected. This was confirmed by students' answers as 51% of them believe that the relationship was negatively affected and only 35% of them believe that it was not affected (Fig. 14a). Moreover, regarding the students' participation during the online lectures, the answers were divided as 26% of them were eager to express their opinion or ask questions during the online lectures, 21% were hesitant and 29% of the students were neutral about it (Fig. 14b).

Overall, the distance learning modality for the project-based courses did not affect the student-student and student-professor relationship, as the students stated that the collaboration with their fellow students and their educators was very good (62% and 76% respectively) (Fig. 14a). These results are encouraging for the future of remote learning, as most educators were worried about the participation and the interaction of the students during the remote classes.

They are also in accordance with the educators' opinion, as 39% of them stated that students had high involvement during the online lectures on the project-based courses (Fig. 15a). Moreover, they stated that the collaboration with the students was very good (23%) or good (54%) (Fig. 15c). Similarly, the communication among them was good (31%) or very good (23%) (Fig. 15d). Their attitude towards the students played an important part in the establishment of such a good relationship with them, as all respondents encouraged their students to express their thoughts during the lectures on the project-based distance learning course. Also, the majority of educators encouraged their students to search on-

a



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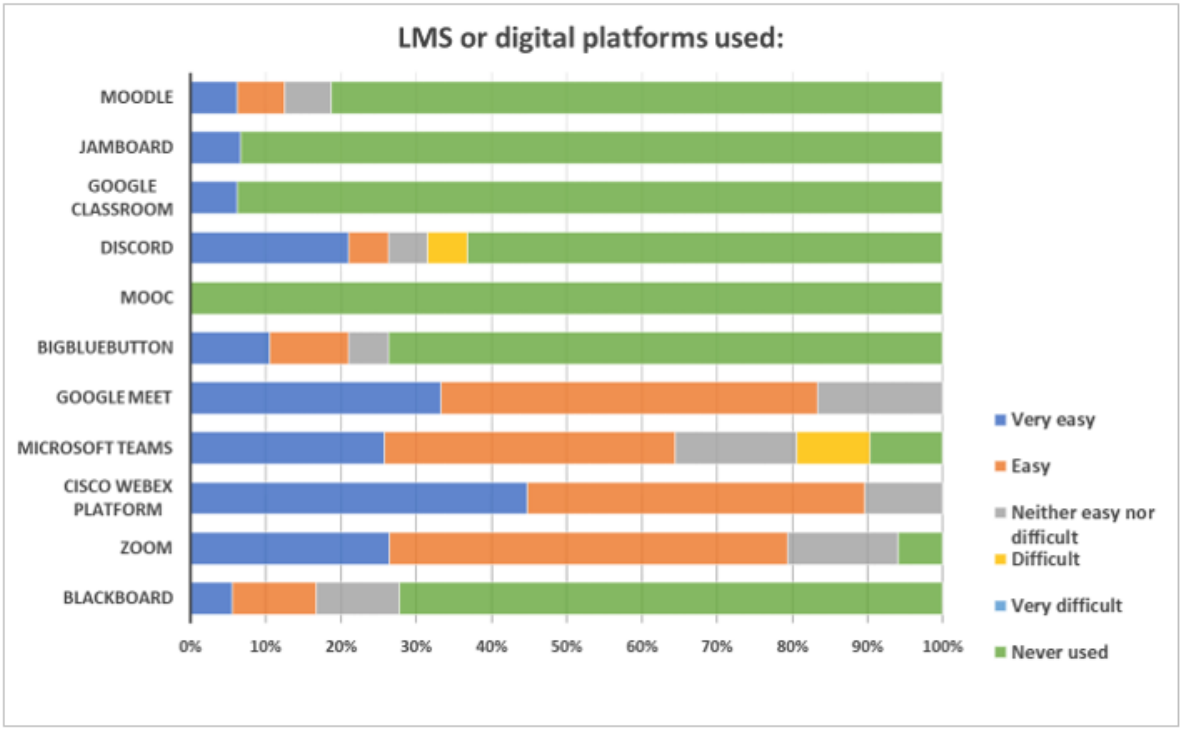

Figure 10: Digital tools used by professors and pedagogical staff during lectures on the project-based courses.

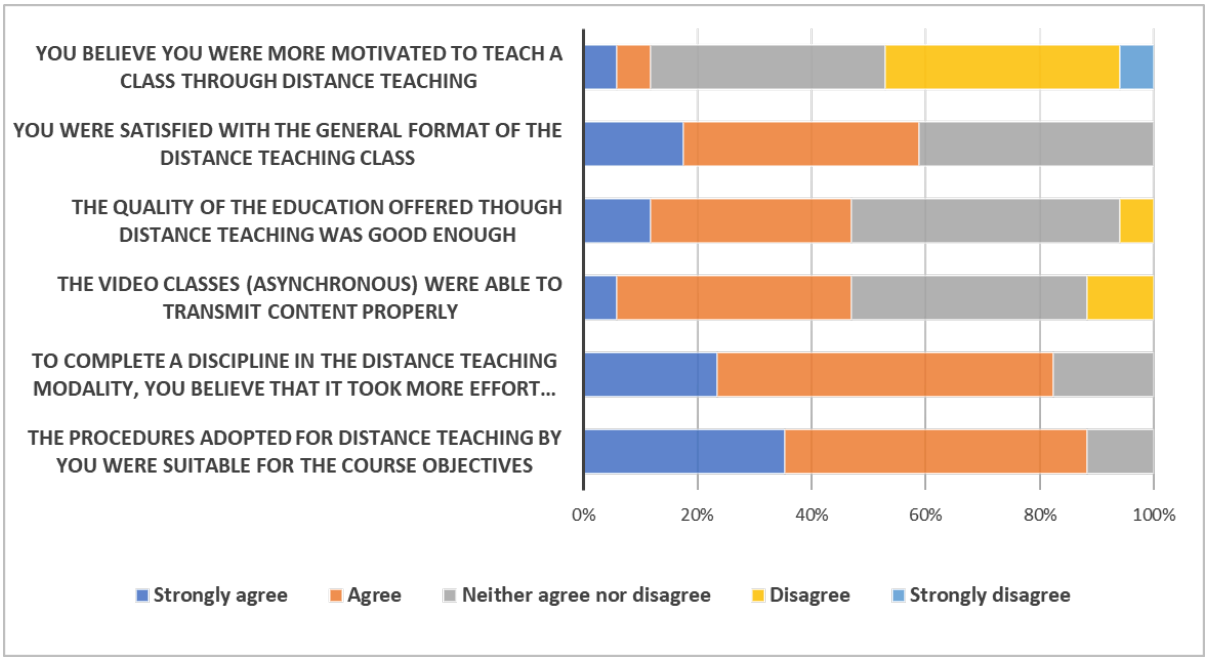

Figure 11: Professors' and pedagogical staff responses regarding the quality of project-based distance learning courses.

line for material relevant to the course and contact them after the class if they had any questions (Fig. 15b).

3.5 Challenges and needs of project-based distance learning courses – Recommendations for improvement

To keep abreast of the distance learning education trends, the respondents were asked how the distance learning modality can be evolved, and how the educational competence of the pedagogical staff could be improved. According to the educators' responses, it would have been helpful to have access to quick courses on online learning (professional development) (25%), websites with lists of useful resources (21%), more free resources and digital tools (18%), easy contact with experts (an ICT technical expert) (14%) and clear guidance for online lectures by the Ministry of Education (11%). However, the least preferred recommendations were: video clips/lesson plans of good practice, more educational tv programs by national media and the creation of webinars and TeachMeet for teachers to share ideas and challenges (0%) (Fig. 16a).

In addition, the creation and use of audio-visual materials, interactive media, simulations, virtual manipulations and virtual tours in lab rooms were considered as very effective ways to improve the lectures on the project-based courses (92%) (Fig. 16b). At the same time 54% of the respondents agreed and 46% of them strongly agreed that the technical skills acquired from distance learning courses, in general, improved the educational competence of the pedagogical staff and professors (Fig. 16c). Similarly, various studies observed that the technological skills required to provide online courses increase the educational competence of the faculty staff members (Rapanta et al., 2020; Zalat et al., 2021).

Similar responses were collected from students, who agreed that the most helpful solutions to

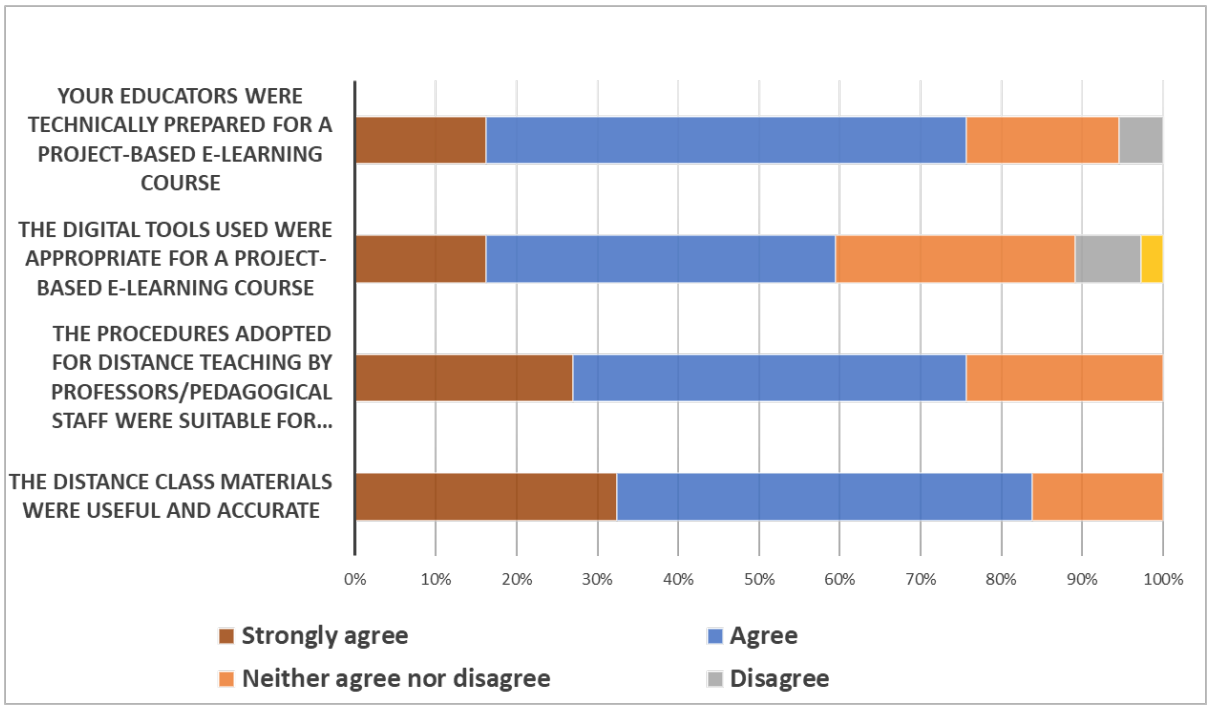

Figure 12: Students' responses regarding the quality and modality of project-based distance learning courses.

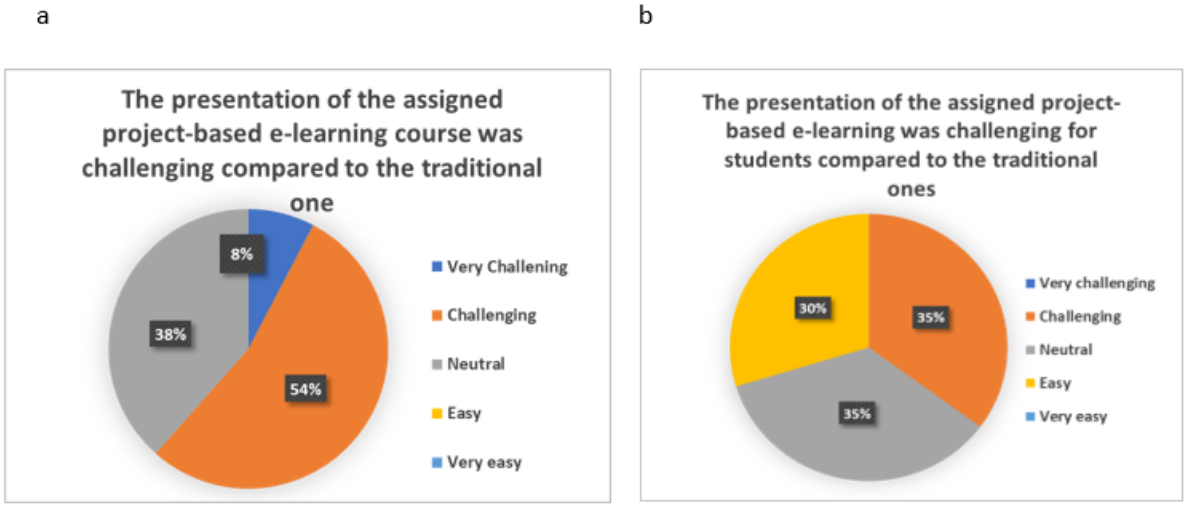

Figure 13: (a) Professors' and pedagogical staff's and (b) students' responses regarding the challenges of the presentation on the project-based course.

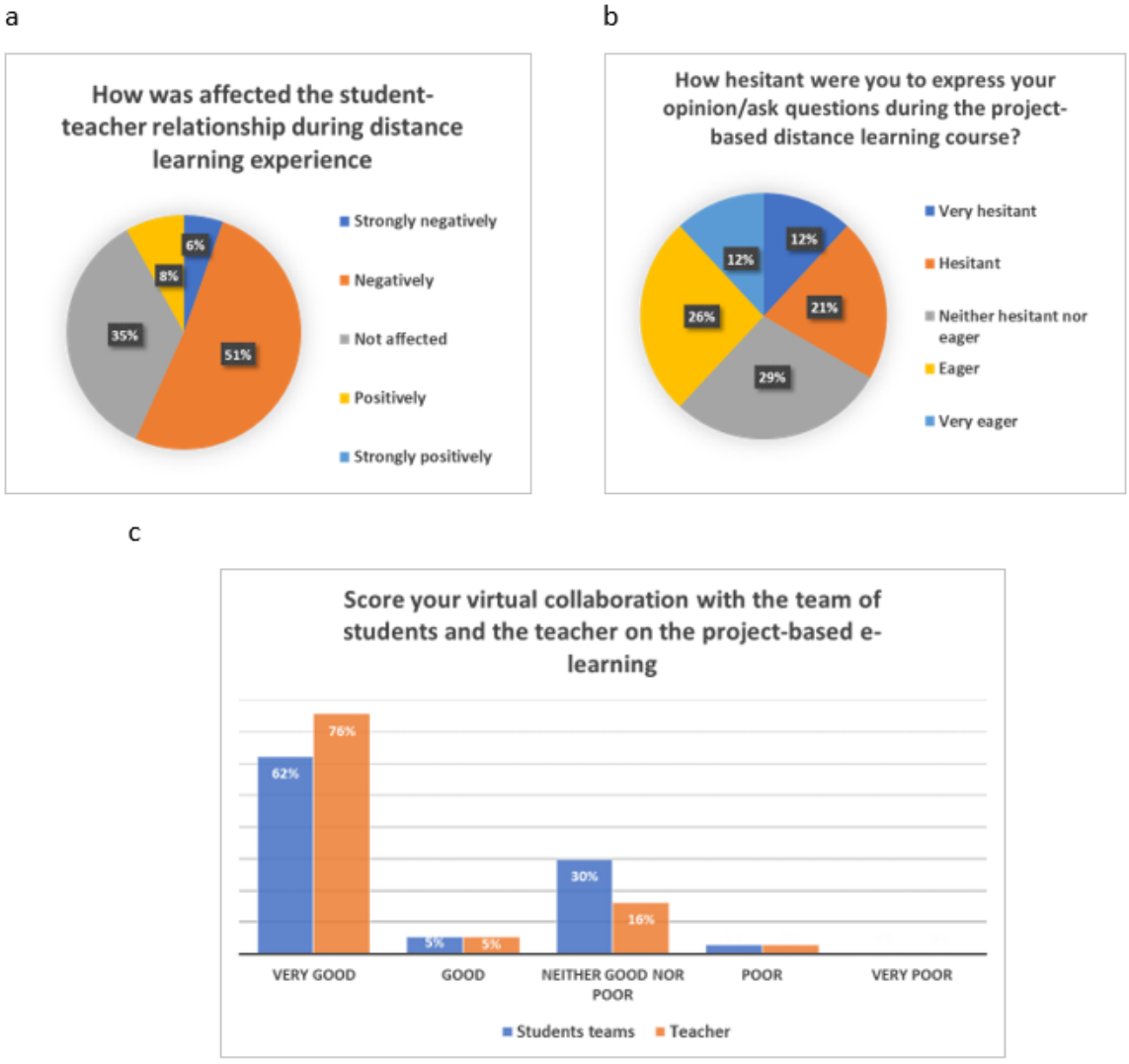

Figure 14: (a) Student-teacher relationship, (b) students' participation and (c) virtual collaboration between the students' team and the educator during distance learning project-based courses.

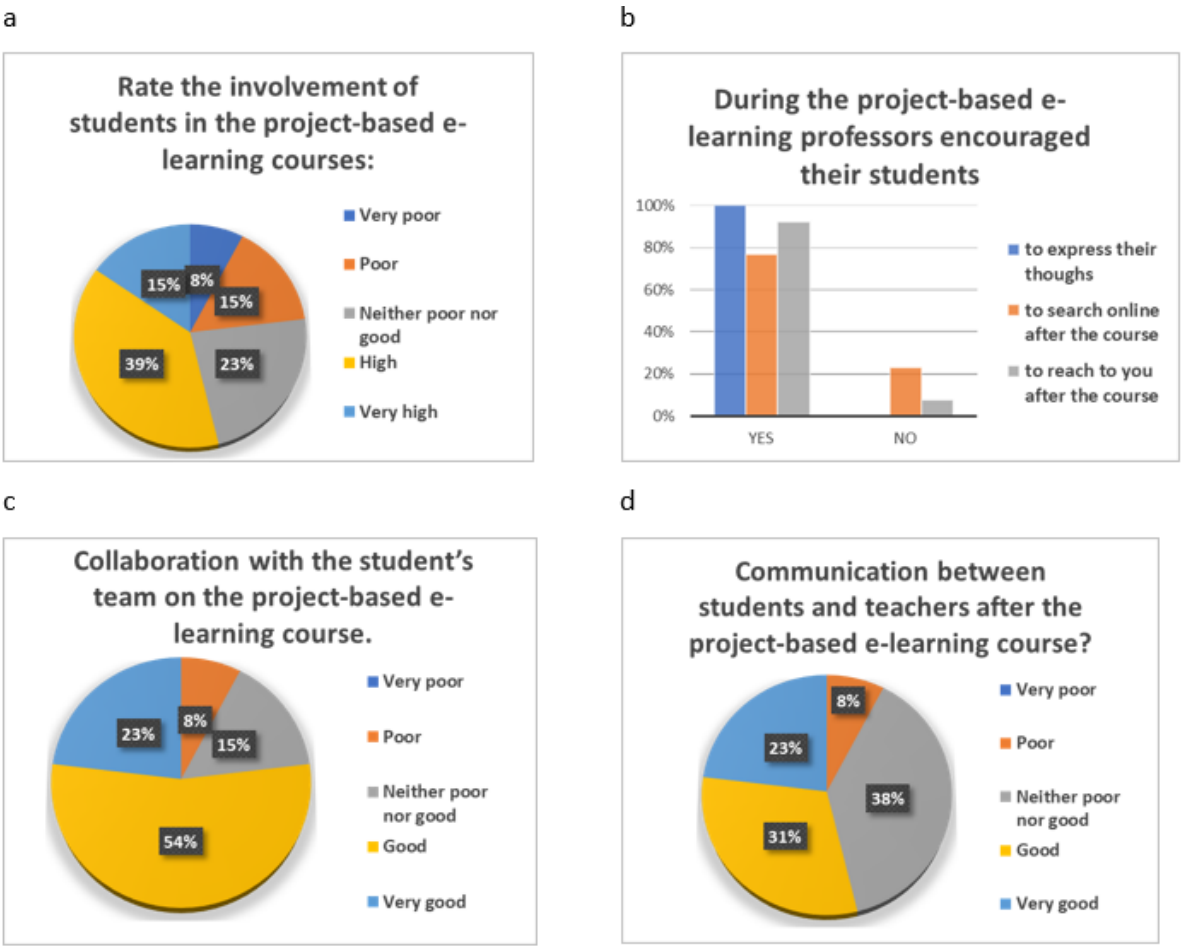

Figure 15: (a-d) Professors' and pedagogical staff's responses regarding the students-teachers dynamic during project-based courses.

support distance learning classes were: the professional development by quick courses on online teaching (14%), access to more free educational resources and digital tools (22%), webinars and TeachMeet for teachers to share ideas and challenges (14%), video clips/lesson plans of good practice (14%) and websites with lists of useful resources (13%). Moreover, the majority of students considered e-learning necessary for the future, as 54% of them agreed that the technical skills acquired from distance learning courses would improve the educational competence of the pedagogical staff and professors. However, regarding the use of audio-visual materials, interactive media, simulations, virtual manipulations and virtual tours in lab rooms as a tool to improve the lectures of the project-based courses, the opinion of the students was divided as 51% of the respondents preferred it, while 49% of them did not (Fig. 17).

However, both students and educators stated that the alternative/virtual laboratories offered by online learning can only fill the theory-into-practice gap. Actually, online learning cannot be effectively and efficiently applied in some disciplines and this compatibility gap is yet to be filled (Adedoyin & Soykan, 2020). Specifically, the students expressed their wish to return with a

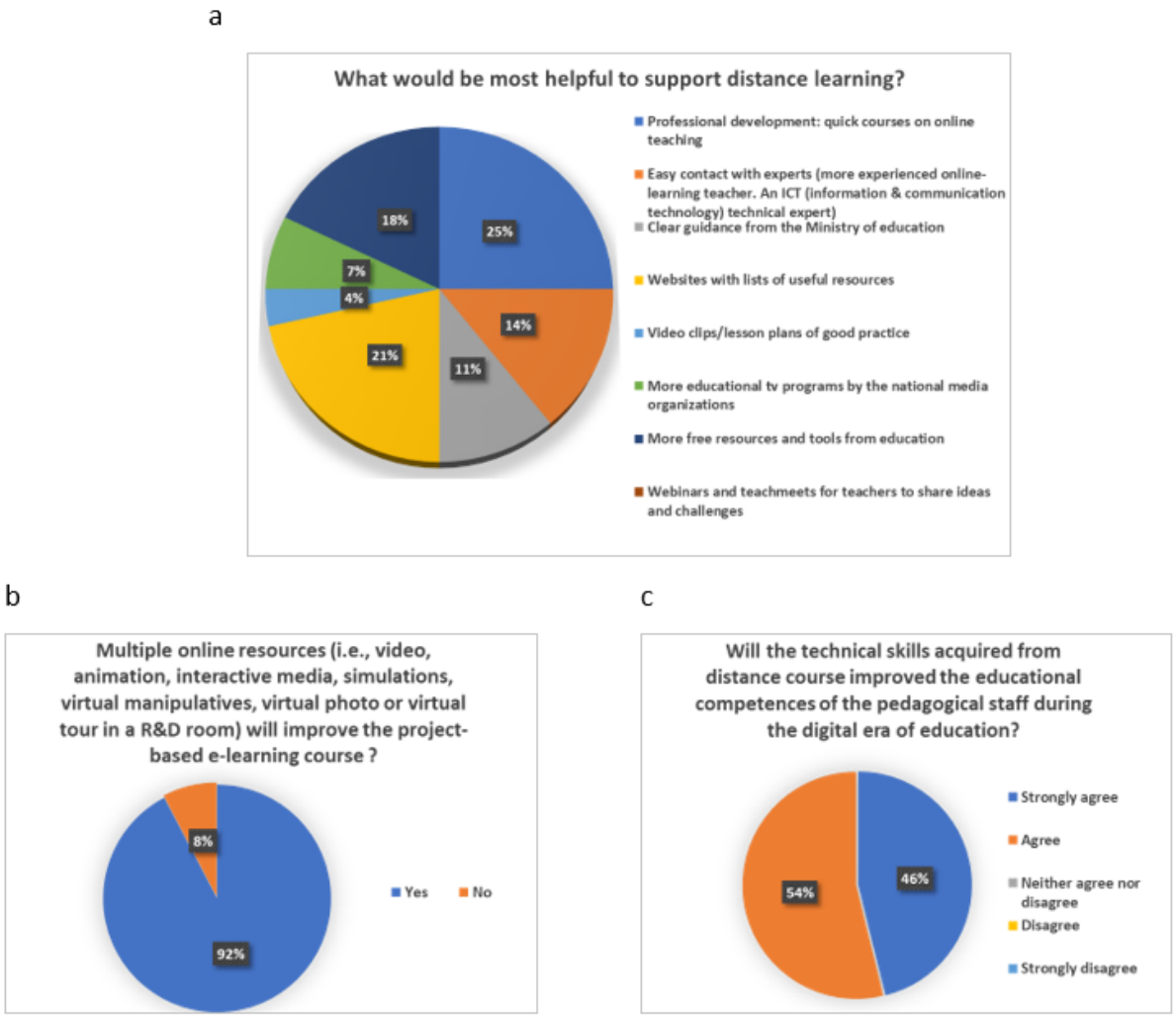

Figure 16: (a-d) Professors' and pedagogical staff's responses regarding the students-teachers dynamic during project-based courses.

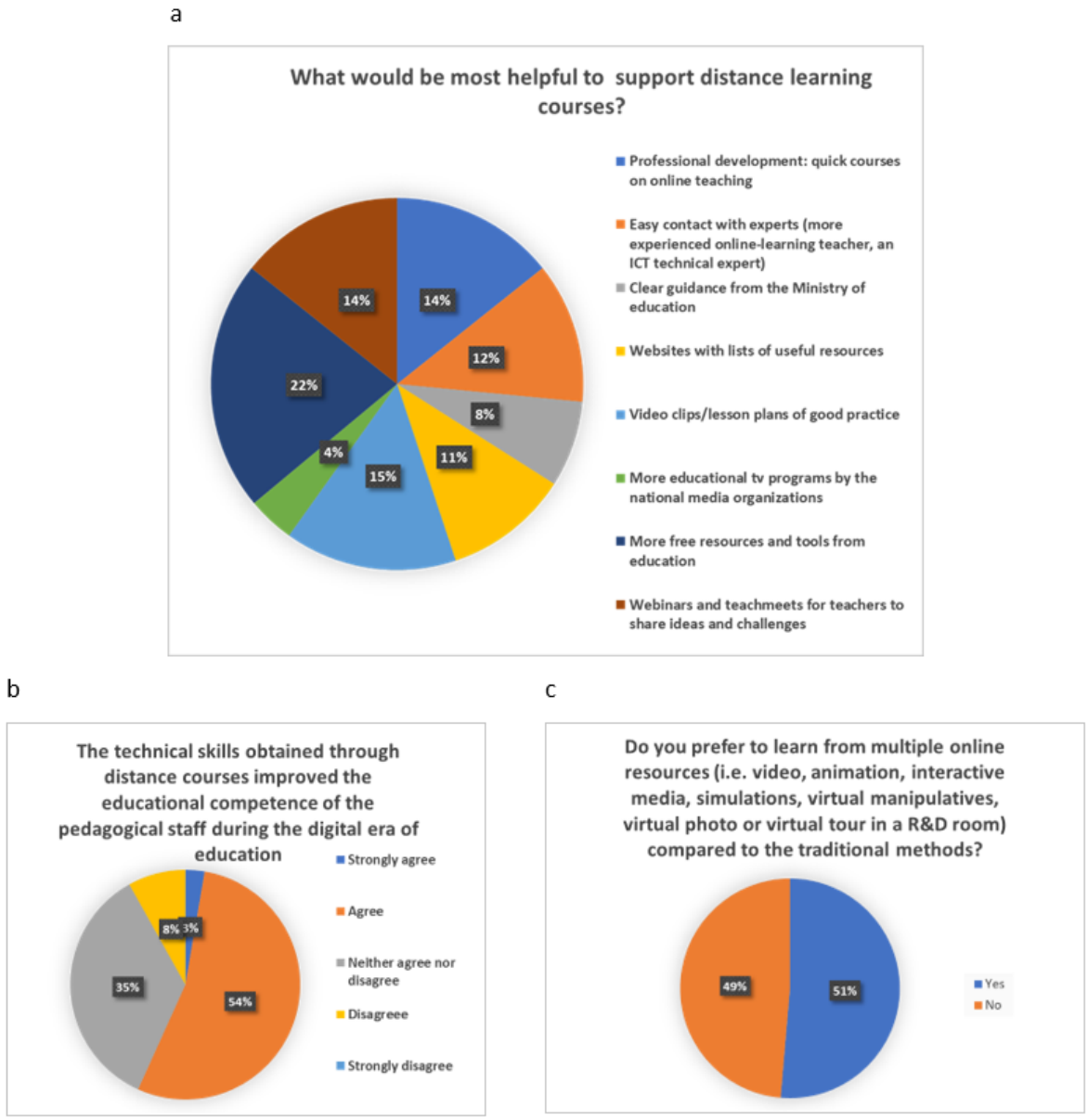

Figure 17: (a-d) Professors' and pedagogical staff's responses regarding the students-teachers dynamic during project-based courses.

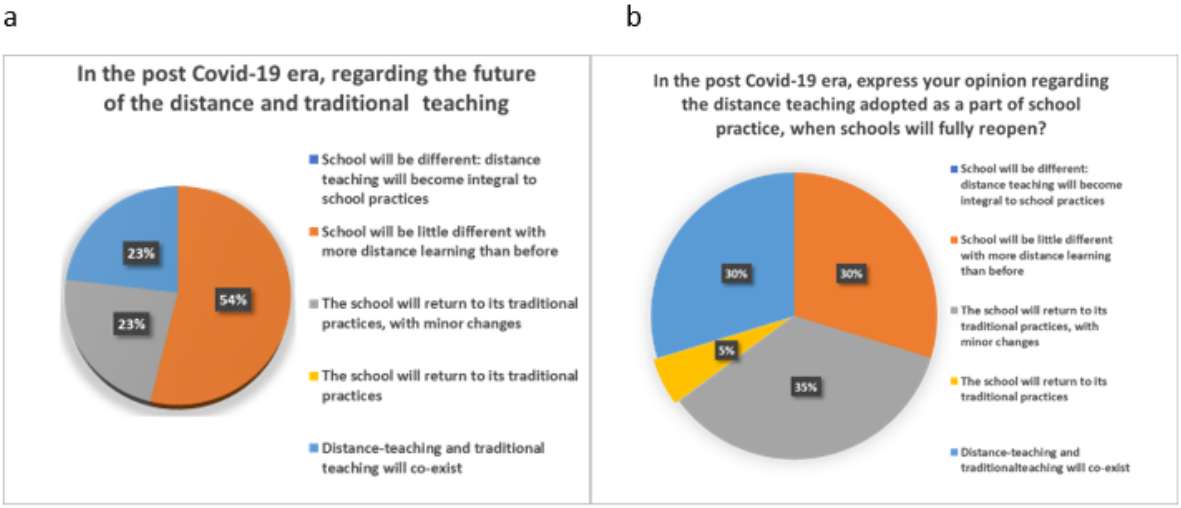

Figure 18: (a-d) Professors' and pedagogical staff's responses regarding the students-teachers dynamic during project-based courses.

physical presence to the laboratories to complete their training. This implies that online learning is not compatible with laboratory practices but can only be used to augment face-to-face training methods where there is later a chance to go back to the normal traditional settings. These remote project-based programs are necessary systems for continuing education but to advance the education process additional work is needed.

Regarding the challenges and the future needs of HEIs towards successful distance learning, some educators mentioned that they faced difficulties with obtaining the required knowledge and skills in order to perform distance learning project-based courses, problems on establishing productive communication and difficulties to deliver the lecture, while they observed minimum interaction during distance learning classes and the discouragement of students to ask questions or to participate in the lecture. They also stated that they initially struggled due to lack of ICT equipment, insufficient internet connection, low motivation or lack of support.

Most students stated that the low internet speed hampered the lectures and disrupted their concentration. It also made them feel anxious and stressed when presenting their projects. Respondents agreed that they faced problems managing the stress caused by the demands of online learning classes, as well as meeting the deadlines and requirements set by the project assignments. Both teachers and students complained about the short period of time available to become familiar with the use of new digital tools and the changes in the learning processes. Specifically, they responded that "the lack of awareness about all the possibilities and uses of online tools available was a problem", or "both faculty and students needed to adapt". Others studies also stated that shifting mindsets is probably the teachers' main challenge to produce and deliver online lectures (Alhawsawi & Jawhar, 2021; Brinkley-Etzkorn, 2018; Martin et al., 2019; Rasheed et al., 2020).

Regarding the distance project-based courses, some educators stated that "maybe in other courses professors had already worked in the distance learning modality but in the project-based or practical courses, we still used a blackboard in face-to-face sessions". However, they suggested that distance learning, when properly implemented and planned in advance, may be useful in some instances. The main problem is the short time they had to move from face-to-face to online teaching. Proper training was considered necessary for educators to enable them to use

the various software available for video recordings among other aspects. All these statements emphasize the need for continuing training on the use of digital educational tools and their incorporation to traditional practices as a means to facilitate transition in times of crisis (Abumalloh et al., 2021).

On the other hand, the respondents stated some positive findings, such as their interest in digital education tools and their expectations for further use in the future, as well as their belief that the intensive use of digital technology in distance education will benefit the educational process and enhance competence.

The respondents agreed that the imposition of distance learning due to the COVID-19 outbreak set a precedent in education and the future will be different. Various studies observed that the great objective impelled by the post-COVID era is the digitization of universities (Amhag et al., 2019; Núñez-Canal et al., 2022). According to this study, the most popular statements are that, in the post-COVID era, the HEIs will be different with more distance learning than before (54%) or that the HEIs will return to their traditional practices, with minor changes (23%) (Fig. 18). The students' point of view is the same, as 30% of the students believe that the HEIs will return to their traditional practices, with minor changes, and 35% of them believe that HEIs will be different with more distance learning than before. Thus, HEIs should carefully plan how to offer distance learning education to their students.

4 Conclusions

This project-based course was delivered in a distance learning modality during the COVID-19 era and the participating students had to work in remote groups. The module focused on integrating theory with practice by means of experimental learning. The study intended to determine if the distance learning approach implemented was successful and efficient for students to develop graduate attributes.

The majority of students and teachers agreed that, despite the short adjustment period, the tools and techniques adopted in distance learning were satisfactory. However, they were divided on the effectiveness of distance education and maintaining the relationship and communication between them. A significant percentage of educators faced difficulties in obtaining the required knowledge and skills to deliver the distance learning project-based courses, problems on establishing productive communication or difficulties in giving online lectures. A common observation was the unexpectedly low level of interaction during distance learning classes and the reluctance of students to ask questions. Adaptation of laboratory or project-based learning courses was less effective as hands-on experience was deemed irreplaceable. Students, in general, readily adapted to the distance-learning modality. However, many of them reported problems with the flow of the online lectures, disruption of concentration and anxiety and stress for meeting the deadlines and requirements for their assignments or project presentations, as well as technical difficulties with respect to internet connection and audio-visual equipment.

According to the results of the survey, when the appropriate tools, techniques, equipment and technical support are available, distance learning can be very useful and provide multiple benefits. However, the ideal is to develop a system that combines traditional teaching with the new methods and digital tools developed or reformed during the pandemic, in order to improve education and achieve maximum interaction and communication among professors and students. It is also recognized that the future remote learning processes, especially in project-based courses, as opposed to the emergency remote teaching applied under the circumstances of the pandemic, should feature in prompt learning analytics, alert systems for those who are passive and personalized feedback from both students and teachers.

Following the digital era of education, the education system should be transformed. HEIs will have to play a vital role in this journey of transition since they are responsible for providing training and workshops for both educators and students and to equip them with the necessary skills and knowledge. The institutions should continue monitoring, evaluating and evolving their educational activities, such as project-based courses, to determine best practices and establish a learning environment that

provides students with the opportunity to deepen and apply their knowledge and develop skills and competencies, enhancing successful employment and career prospects.

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Needs to Change Behaviour in Households Producing Lots of Food Waste

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Abstract

The purpose of this research was to investigate avoidable food waste among households of students studying in higher education in Seinäjoki. The focus was to quantify the avoidable food waste in different-sized households. The focus was also to specify food categories wasted, and the main reasons for avoidable food waste accumulated. The participating households weighed all their food waste during the one-week monitoring period recording the data on an Excel spreadsheet. The university students taking part in the study were introduced to the work by video instruction. In total 421 households with 918 persons took part in this study. It was found that the average amount of avoidable food waste was equal to 25.2 kg/person/year. In single person households, the amount was 36.6 kg/year. The amount for households with five or more persons was 80.0 kg/household i.e. 14.1 kg/person. This research showed that 25 % of the households caused 56 % of the avoidable food waste, which means that main efforts should be targeted to this 'heavy wasting' group. One way of improving the good practices would be to share good habits related to lowering food waste among university students through peer learning. This study is aimed to awaken the 'heavy wasting' university student to change their attitude and behaviour.

Keywords: Avoidable food waste; Waste reduction; Type of food waste; Reasons for food waste; Finnish university students as consumers

1 Introduction

1.1 Definition of food waste

Definitions of food waste and food loss vary widely in the literature, which means that research on food waste is not directly comparable (Bräutigam et al., 2014). The terminology used within this study relied on the definitions used in international and European comparative studies and meta-analyses (European Commission, 2010). 'Food loss' refers to the decrease in edible food mass throughout the food chain where edible food is prepared. 'Food waste' is described as loss occurring at the end of the food chain e.g., in retail and during final consumption (Parfitt et al., 2010). It relates to both retailers' and consumers' behaviour and takes place during post-harvest and in processing of food (Parfitt et al., 2010). In the processing stages, the reasons for food waste can be e.g., poor food preparation technique, inappropriate packaging technique, microbial or chemical contamination, spillage, poor storage conditions, lack of cooling facilities or cold storage, inappropriate conditions during transportation, as well as misunderstanding of 'best before' and 'use-by' dates (Parfitt et al., 2010). The term 'Avoidable or

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edible food waste' consists of food thrown away prior to disposal and includes bread slices, fruit, cold cuts of meat etc. (European Commission, 2010). Silvennoinen et al. (2014) reported that the food waste in households can be divided into at least two types: 'avoidable' e.g., leftovers due to too much production as well as bio-waste e.g., bones, skin, tea leaves and coffee grounds. In the preparatory study on food waste across EU 27 (2011) 'possibly avoidable food waste' was described as food that some people eat, and others do not eat e.g., bread crusts and potato peels. In the same report 'unavoidable food waste' was defined as waste arising from food preparation e.g., bones, egg shells and peel of various fruits" (European Commission, 2010). In this research, food waste was defined as avoidable food waste.

1.2 The amount of food waste

In 2011, the Food and Agricultural Organization of the United Nations (FAO) stated that consumers in Europe and North America produce 95-115 kg food waste annually. Finland, as a part of the European Union, is working on halving the food waste by 2030. Furthermore, the target is to be climate-neutral by 2050 i.e. to be an economy with net-zero greenhouse gas emission (European Commission, 2020). In the Finnish food chain, a lot of the waste is accumulated in the households which is also the case in many other EU countries (European Commission, 2010). Several studies have been carried out in recent years in relation to food waste in the households (e.g., Aitsidou et al. (2019), Cantaragiu (2019), Delley and Brunner (2018), Herzberg et al. (2020), Landry and Smith (2019), Lanfranchi et al. (2016), Pellegrini et al. (2019), and Szabó-Bódi et al. (2018).
The amount of consumers' food waste in industrialised countries was almost as high as the total net food production in sub-Saharan Africa, respectively 222 billion kilograms and 230 billion kilograms (FAO, 2011). On global level, FAO estimated that roughly one-third of food produced annually, approximately 1.3 billion tonnes, for human consumption was either lost or wasted (FAO, 2011). Silvennoinen et al. (2022) stated based on their research that the annual originally edible food waste in Finnish households was 23-28.4 kg/person. The amount of available food per person has increased during the last few decades in both the USA and the EU. One of the most important reasons for large amounts of consumers' food waste in developed countries is that people can 'afford' wasting the food cultivated and/or purchased. Retail stores offer large bargain packages and food manufactures produce oversized ready-to-eat (RTE) meals (FAO, 2011), which still can be seen in shops today. Buffets in restaurants serve food at fixed prices, which incite consumers to fill their plates with more food than they can actually eat (FAO, 2011).

1.3 Reduction of food waste

Wasted food is thus a burden on both economy and climate (European Commission, 2010). The sooner food systems are improved, the better, because the climate is strongly affected by food and drink waste produced in the households (Quested et al., 2011). Meeting the targets require cooperation between food producers, research organisations and consumers. Practical tools to monitor food waste and the possible reduction across the entire food chain continuously are also needed. Furthermore, the manufacturers should collaborate with the retailers on timely orders, working with optimization of packaging and through recycling to reduce food waste (WRAP, 2020).
The consumer attitudes and abundance of products lead to lots of food waste especially in industrialised countries (Beretta et al., 2013). There are knowledge gaps in our understanding of what drives the wasting behaviour (Schanes et al., 2018; Visschers et al., 2016). Interventions should be well designed and adequately evaluated (Hebrok, 2020). Today there is substantial academic and societal interest in finding ways to intervene to reduce the wasting of food in households (Beretta et al., 2013). This interest has commonly focused on avoidable food waste and not on unavoidable food waste e.g., vegetable peels and bones (WRAP, 2009). In the reduction of household food waste, effective policies and programmes have been developed (Hebrok, 2020; Schanes et al., 2018).
Pietilä (2019) reported an empirical study on consumers' motivation and knowledge about re-

ducing food waste. The main findings showed that young adults are aware of the responsibility to reduce food waste and many are motivated to do it. An effective motivator is environmental concerns. Morals also play a big role in this issue. People must be motivated to change e.g., to use leftovers and to plan shopping more carefully. Thus, the food waste will be reduced (Pietilä, 2019).

Much research has not shown any significant correlation between education level and amount of food waste (Herzberg et al., 2020). On the other hand, the study by Marangon et al. (2015) gives an indication that the wastage of food increases with growing educational qualification. Also Secondi, Principato et al. (2015) found that persons that are more educated generate more food waste than less educated. Active students take learnt behaviour further and the whole food chain is affected in a positive way. Thus, it is important to affect the behaviour of young, high-educated consumers.

In this paper, we report research that focused on finding out the amount and the type of avoidable food wasted in the households with students at Seinäjoki University of Applied Sciences. The major purpose of this research was to quantify the avoidable food waste in different-sized households and to specify the dominant food categories of avoidable food waste accumulated in Finnish households with university students. Furthermore, the main reasons for avoidable food waste accumulated were investigated. Avoidable food waste was defined similarly as in Silvennoinen et al. (2014), i.e. all wasted food and raw materials that could have been eaten, if stored or prepared differently. Vegetable peelings, coffee grounds, tea leaves, eggshells, bones etc. were not included.

2 Materials and Methods

The participating households quantified all their food waste through weighing during the one-week monitoring period starting on Monday and ending on the following Sunday. The one-week monitoring period was also used in the study of Szabó-Bódi et al. (2018). In the study by van Herpen et al. (2019) it was concluded that the diary study method was suitable to understand the relative amount of food waste.

The data in this study was collected in 2019 - 2020. The respondents in the study did not correspond to the average population in Finland. They were students in a university of applied sciences with interest in the agri-food area. The students carried out the data collection as a task in two selected courses related to sustainable food systems and they were arranged twice in this period. The courses were arranged different times of the years. This task was mandatory, and it included two assignments, one on avoidable food waste and the other on food package waste. Depending on the course implementation the students carried out either both or only one of the tasks according to the student's choice. Each student performed the study in his/her own household, in which at least one participant was a university student. These students were young students or adults with children i.e. they represented various age groups. In Finland, the university students live in apartments with either kitchen or at least kitchenette facilities.

The study was performed using a formal Excel sheet in which the students marked the avoidable food waste during one week. They weighed the food waste using kitchen scales and recorded the results in the Excel sheet. There were similar tables for every day in the Excel sheet. The following food categories were used in this study: vegetables, berries, fruits, potatoes, rice and pasta, cereals including bread, oil and margarine, milk and milk products, fish, poultry, red meat, convenience food, and other. The students reported their reasons why food was wasted both verbally and using weighing results. The reasons can be compared to the work of Silvennoinen et al. (2014): the best before date was expired, used-by date was expired, food was spoiled, the respondent was uncertain about eatability of food, too large pack size, prepared too much, bought fresh or other food instead, plate leftovers, and other reasons. The monitoring period was meant to be as normal as possible, so the respondents did not get any further instructions to omit any foodstuffs like outdated food or leftovers in the beginning of the monitoring period. The students participated in various study courses, and they were allowed to choose the week in which they

made the findings of food waste.
Quested et al. (2020) stated that there are some limitations related to this kind of food-waste diary studies i.e. the respondents might underestimate the amount of the food waste.Quested et al. (2020) have grouped those limitations to the following groups: behaviour, misreporting, and biases due to measurement and selection. In this study, the behavioural aspects may have influenced the responses of a part of the university students. Selection biases mentioned by Quested et al. (2020) was the weakness of this study. On the other hand, some students were reporting the amount of food wasted very accurately. Those that reported zero food waste in this study explained the reasons of the outcome. None of responses with zero waste without explanations were approved. Measurement biases were minimized through advising the students to weigh the food waste. The students were introduced to the monitoring work by using an introductory video. In the video, the researcher described how to monitor and report the household's food waste.
After collecting data, every Excel sheet was checked for faults. Seven Excel sheets were not filled accurately, and they were rejected. The reasons for rejection were incompleteness in background information and/or in weighing data. In total, there were 421 accurate data sheets collected over a period of two years. The approved sheets with raw data were thereafter merged into one Excel file. Firstly, respondents' background information, i.e., the size of households and age of members in the households, was analysed. Secondly, the total amount, type and reason of food waste were studied. Finally, the combination of households and food waste were investigated and reported according to the size of households.

3 Results and Discussion

3.1 Background information of households

In this study, totally 421 households did produce reliable and acceptable data (Table 1, centre). This data includes information of a total of 918 persons including both students and their family members (later respondents). Half of the respondents (51 %) were 19 - 40 years old. Due to the fact, that the youngest students were 19 years old the age classification was split between 18 and 19 years age (Table 1, upper part).
One third of respondents were 18 years old or younger. The biggest group (38 %) was single person households. The second biggest group (34 %) was households with two persons and out of these 8.4 % were single parent households (Table 1, centre).
Almost one third (31 %) of people were from two-person households. The sizes of other households included similar amount of people (Table 1, lower part).

3.2 Amount and type of food waste in different-sized households

The results shown in Table 2 revealed that single person's households produced more waste than other groups in average per person. The same kind of results are also reported by Quested et al. (2011) as well as Silvennoinen et al. (2014). This study revealed that when the number of persons in households increased the average food waste per person decreased. The same type of results were also reported by Herzberg et al. (2020) and the Luke-research group (Silvennoinen et al., 2014).
In two, three and four person-households the food waste was quite similar per person. The variation in the amount of food waste was wide, especially in the groups of one- and two-person households. In those households the standard deviation was bigger than the average. Some households did not produce food waste at all (4.3 %), and some produced very large amounts of avoidable food waste (Figure 1). Attitude to food and food appreciation in zero food waste households was high. These households paid attention to their food consumption. Furthermore, the Finnish food prices are high (Eurostat, 2022), which affected the amount of food wasted especially for students. The upper quartile for total households included those households in which the food waste was at least 715.5 g/person i.e.

Table 1: Background information of respondents

	Number	%
Age		
<12	147	16.0
12-18	166	18.1
19-24	214	23.3
25-30	120	13.1
31-40	131	14.3
41-50	86	9.4
>50	54	5.9
Total	918	100.0
Size of household		
1	158	37.5
2	143	34.0
3	49	11.6
4	45	10.7
≥5	26	6.2
Total	421	100.0
Total number of persons in households		
1	158	17.2
2	286	31.2
3	147	16.0
4	180	19.6
≥5	147	16.0
Total	918	100.0

heavy wasting group. Those 106 households produced 55.6 % of total food waste.

The average amount of food waste was 484 g per person in this one-week study (Table 2), which equals 25.2 kg per person per year. By analysing the Hungarian results compiled by Szabó-Bódi et al. (2018) the amount of avoidable food waste was 637 g/ person/week, which corresponds to 33 kg/person/year. Correspondingly, Silvennoinen et al. (2014) stated that the annual average of food waste was 23 kg/person.

According to the study (Table 3) fruits and vegetables including potatoes was the biggest group of food waste, second biggest was milk and milk products and the third was meat and fish. The waste of fruit and vegetables (Table 4) divided into the three big groups: 1) vegetables including root vegetables except potatoes, 2) potatoes and 3) fruits. The fourth group in this category was berries, but waste of fruits and vegetables corresponded only to 5 % of the total share. Waste of potatoes was almost as big as the vegetable waste. In Finland the consumption of potatoes is more common than rice and pasta. Consumption of potatoes was 46.2 kg/person in 2016. Correspondingly, the rice share was 5.9 kg (Luke, 2020). The third group, meat and fish (Table 5), corresponded to a ninth of the total food waste. Other studies are not directly comparable due to their different categorisation of food. Silvennoinen et al. (2014) reported that the biggest groups of food wasted were vegetables, potatoes; home cooked food and milk products. This is similar to the results in this study, but in this study home cooked food was divided into other categories. Szabó-Bódi et al. (2018)

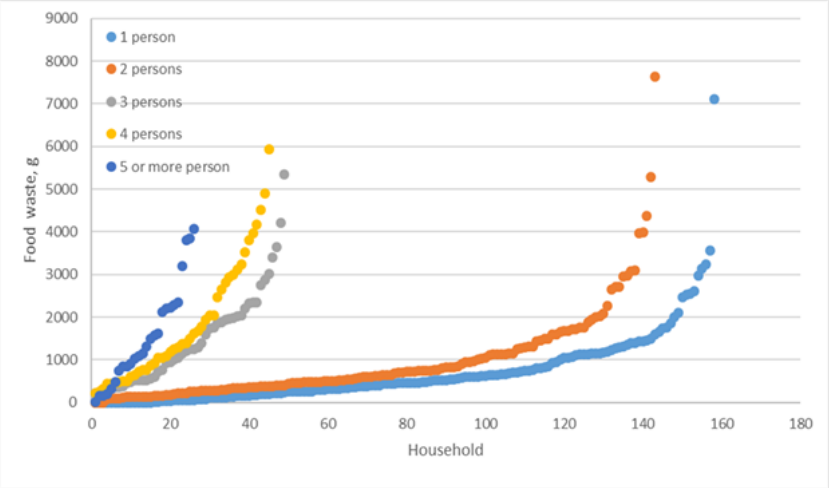

Figure 1: The amount of food waste during one week in the investigated households, the households comprised from single person to multi-person households. There were totally 421 investigated households.

reported that 56 g/person dairy products were wasted a week. In this study, there were more milk products wasted i.e. 98.4 g/person/week.
Almost two thirds (62.4 %) of food waste is related to food spoilage or eatability quality. Giordano et al. (2019) stated similarly that the most frequently reason for food waste was spoilage. Waste of milk and milk products was mostly due to the spoilage or uncertainty of eatability (82 %), waste of fish and meat was respectively 56 % and fruit and vegetables 70 % (Tables 3-5). The percentage of fruit waste was 88 for spoilage and uncertainty of eatability. Best before or use-by date expired account for one fifth of the total food waste (Table 3).
Waste per person in single households was bigger than waste produced in households with two or more persons (Table 6). In particular, the difference in waste of milk products was very large, when compared to the other households. Single person households wasted almost five times more than in households with five or more persons (Table 6). The difference in cereal wasted was not so big, when comparing sizes of households. Single person households wasted 1.7 times more cereals than households with five or more persons (Table 6).

3.3 Reasons of food waste

In Table 7, the results were calculated using the percentage and amount of food waste per household. Furthermore, the amount per capita was calculated both in all households and in the heavy wasting group. The total amount of food waste was 2.6 times bigger in single person households compared to the households with five or more persons. Best before date or use-by date expired was more common reason for waste in single person household than in bigger households. The reason “spoiled” was the most common in households with two or more persons. Table 7 shows that the best before date or use-by date expired was the most common reason for food waste also in heavy-wasting, single person households. Correspondingly, ’spoiled’ was the most common reason for heavy-wasters in households with two or more persons.
The reason ’bought fresher/other food instead’ was not common for wasting food in any size of households. Uncertain of eatability was equivalent to 10-12 % independently of household size. ’Prepared too much’ was a common reason for wasting food in households with two or more persons and ’plate leftovers’ for households with three or more persons. In single person house-

Table 2: Amount and distribution of food waste in different-sized households taking part in the one-week study. The average amount of food waste per person was calculated based on facts from the households.

Size of household	Average, g	Standard deviation	Standard error	Lower quartile	Median	Upper quartile	Average g/person	Upper quartile, g/person
1	704,7	874,7	69,6	166,3	455,5	998,8	704,7	998,8
2	968,0	1078,8	90,2	329,0	628,0	1205,0	484,0	602,5
3	1484,5	1137,6	162,5	524,0	1260,0	2020,0	494,8	673,3
4	1826,4	1419,6	211,6	720,0	1375,0	2805,0	456,6	701,3
≥5	1537,5	1188,9	233,2	759,3	1232,5	2212,3	271,9	379,0
Total *	**1056,2**	**1127,4**	**54,6**	**320,0**	**648,0**	**1400,0**	**484,4**	**715.5**

*Upper quartile for total households includes those households in which the food waste was at least 715.5 g/person.

Table 3: Total food waste according to the type of food and the reason why the food is wasted

	Fruits and vegetables, g	**Rice and pasta, g**	**Cereals e.g. bread, g**	**Oil and margarine, g**	**Milk and milk products, g**	**Meat and fish, g**	**Convenience food, g**	**Other, g**	**Total, g**	**Share of total waste, %**
Best before date or use-by date expired	8114	624	6402	1942	50402	14958	8519	2993	93953	21,1
Spoiled	77233	1495	19729	300	16485	5017	3384	3672	127316	28,6
Uncertain of eatability	24789	3494	3988	62	6854	8221	3288	5576	56272	12,7
Too large pack size	1634	445	2580	100	6172	1019	4453	1548	17951	4,0
Prepared too much	18878	19362	5523	30	1484	8531	5418	4135	63361	14,2
Bought fresher/other food instead	2856	1147	1718	0	2020	1889	300	434	10364	2,3
Plate leftovers	13834	5515	5964	98	4873	7987	5411	3860	47542	10,7
Other	11104	1102	1668	95	2021	2927	2723	6271	27911	6,3
Total	158442	33184	47572	2627	90311	50549	33496	28489	444671	100,0
Share of total waste, %	35,6	7,5	10,7	0,6	20,3	11,4	7,5	6,4	100,0	

Table 4: Food waste of fruit and vegetables and the reason why this type of food is wasted

	Vegetables, g	**Berries, g**	**Fruits, g**	**Potatoes, g**	**Total, g**	**Share of total fruit and vegetables waste, %**
Best before date or use-by date expired	1922	100	842	5250	8114	5.1
Spoiled	26802	3929	35304	11198	77233	48.7
Uncertain of eatability	10725	1783	6567	5714	24789	15.6
Too large pack size	928	451	100	155	1634	1.0
Prepared too much	5933	100	145	12700	18878	11.9
Bought fresher/other food instead	490	0	1365	1001	2856	1.8
Plate leftovers	5128	477	979	7250	13834	8.7
Other	4468	1477	3436	1723	11104	7.0
Total	56395	8317	48739	44991	158442	100.0
Share of total fruit and vegetables waste, %	35.6	5.2	30.8	28.4	100.0	

Table 5: Food waste of meat and fish and the reason why this type of food is wasted

	Fish, g	**Poultry, g**	**Red meat, g**	**Total, g**	**Share of total meat and fish waste, %**
Best before date or use-by date expired	5679	4963	4316	14958	29,6
Spoiled	350	2010	2657	5017	9,9
Uncertain of eatability	821	2719	4681	8221	16,3
Too large pack size	70	404	545	1019	2,0
Prepared too much	985	2406	5140	8531	16,9
Bought fresher/other food instead	973	581	335	1889	3,7
Plate leftovers	1762	2935	3290	7987	15,8
Other	1453	632	842	2927	5,8
Total	12093	16650	21806	50549	100,0
Share of total meat and fish waste, %	23,9	32,9	43,1	100,0	

holds, the alternatives 'prepared too much' and 'plate leftovers' were not common. Too large pack size was the most common reason in single person households (Table 7). In Finland, 45% of the households are single person households (Official Statistics of Finland, 2020) and the number of these households will increase further, thus it is vital to enable the single person households to reduce their food waste. The food industry and retail stores should offer suitable package sizes to affordable prices to persons in small households. The food package could be segmented into smaller parts i.e. the consumer can open only one segment at one time and the rest of the segments are still sealed. Longer self-life helps households to reduce avoidable food waste. The food industry can play a crucial role in finding new solutions to extend the shelf-life of packed products.

Herzberg et al. (2020) drew similar conclusions. They stated that there are challenges in purchasing appropriate amounts of food products in small households. Furthermore, they also stated that households with children had challenges in preparing suitable amounts of food. Principato et al. (2015) stated the importance of planning food purchases. A shopping list especially helps young people in buying complementary food and thus it is a vital part in reducing food waste.

In the heavy wasting group, the reasons for food waste were investigated deeper using the open-ended answers. The explanations revealed that food was wasted at least once a week due to spoilage in 87 % of households and correspondingly 60 % prepared too much and 53 % was based on negligence. With negligence it is meant that food was stored or prepared wrongly. Many times, food in big amounts was ruined because it was left at room temperature instead of being properly refrigerated. These persons need to plan their food purchases, avoid impulse purchases and more properly deal with their purchases. They should also learn to use their senses i.e. taste, smell and appearance in evaluating the eatability of food.

4 Conclusions

The average avoidable food waste in this study was 484 g per person per week, which equals 25.2 kg per year. When number of persons in households decreased the average avoidable food waste per person increased. In single person households the average avoidable food waste was 36.6 kg per year, correspondingly the annual avoidable food waste in five or more persons' households was 80.0 kg, which corresponded to 14.1 kg per person. In two, three and four person-households the annual food waste was quite similar per person, the amounts were 25.2 kg, 25.7 kg and 23.7 kg.

The variation between households was wide, the median was lower than the average in all household sizes. Furthermore, the standard deviation was bigger than usual in one and two person households. These facts show that the waste

Table 6: Type of food waste according to the size of household.

	% of waste					waste (g per houshold)					waste (g per person)				
Size of household, persons	1	2	3	4	≥5	1	2	3	4	≥5	1	2	3	4	≥5
Fruits and vegetables	37,1624	33,916	33,7294	36,8165	38,3315	261,889	328,297	500,722	672,422	589,346	261,889	164,149	166,907	168,106	104,238
Rice and pasta	5,09492	6,49329	11,303	9,45872	6,32145	35,9047	62,8531	167,796	172,756	97,1923	35,9047	31,4266	55,932	43,1889	17,1905
Cereals (e.g. bread)	8,15463	10,6909	12,3089	11,8435	12,5228	57,467	103,485	182,729	216,311	192,538	57,467	51,7427	60,9095	54,0778	34,0544
Oil and margarine	1,01217	0,72966	0,49215	0,08517	0,1551	7,13291	7,06294	7,30612	1,55556	2,38462	7,13291	3,53147	2,43537	0,38889	0,42177
Milk and milk products	27,2186	22,4433	14,1301	15,7134	14,3715	191,814	217,245	209,765	286,991	220,962	191,814	108,622	69,9218	71,7478	39,0816
Meat and fish	10,2744	12,3906	12,9557	9,67652	11,4597	72,4051	119,937	192,331	176,733	176,192	72,4051	59,9685	64,1102	44,1833	31,1633
Convenience food	6,50231	5,37639	9,15992	10,1084	9,61351	45,8228	52,042	135,982	184,622	147,808	45,8228	26,021	45,3272	46,1556	26,1429
Other	4,58054	7,95984	5,92093	6,2978	7,22452	32,2797	77,049	87,898	115,024	111,077	32,2797	38,5245	29,2993	28,756	19,6463
Total	100	100	100	100	100	704,715	967,971	1484,53	1826,42	1537,5	704,715	483,986	494,843	456,604	271,939

Table 7: The reasons of food waste according to the size of households.

	% of waste					waste (g/household)					waste (g/person)					Heavy wasting group: waste(g/person)				
Size of household, persons	1	2	3	4	≥5	1	2	3	4	≥5	1	2	3	4	≥5	1	2	3	4	5
Best before date or use-by date expired	28,2	21,4	18,2	14,5	19,6	199	207	271	264	301	199	103	90,2	66	53,3	537	323	217	150	120
Spoiled	25,8	32,2	28,5	28,2	25,3	182	312	423	515	389	182	156	141	129	68,8	352	370	315	290	223
Uncertain of estability	13,4	13,7	13,4	9,78	11,5	94,2	133	199	179	177	94,2	66,3	66,5	44,7	31,3	196	128	163	62	145
Too large pack size	7,51	3,29	2,48	1,48	5,06	52,9	31,8	36,8	27	77,8	52,9	15,9	12,3	6,74	13,8	125	53,2	30,3	9,45	0
Prepared too much	8,07	13,8	19,8	17,9	15,5	56,9	133	294	326	239	56,9	66,6	98,2	81,5	42,3	151	195	183	186	16,3
Bought fresher/other food instead	3,53	2,16	0,16	2,78	2,61	24,9	20,9	2,31	50,8	40,2	24,9	10,4	0,77	12,7	7,11	74,7	22,8	3,03	34,2	56,8
Plate leftovers	7,39	6,99	14	17,7	12,3	52,1	67,7	208	323	190	52,1	33,8	69,3	80,6	33,5	113	80,1	102	174	113
Other	6,11	6,53	3,35	7,81	8,04	43,1	63,2	49,7	143	124	43,1	31,6	16,6	35,7	21,9	59,8	76,5	30,9	73,9	106
Total	100	100	100	100	100	705	968	1485	1826	1538	705	484	495	457	272	1610	1248	1044	979	781

varied from zero to large amounts of avoidable food waste. This emphasises that those households, which produce huge amount of food waste, have challenges in both attitudes and behavioural habits. Those heavy-wasting households were negligent in handling food.

The weight results revealed that fruits and vegetables including potatoes was the biggest group of food waste, second biggest was milk and milk products and the third was meat and fish. Milk and milk products, especially, were wasted in large amounts, even though properly processed and packaged milk products like yoghurt are safe to use after the best before date when the cold chain has remained intact during transportation and storage (Mercier et al., 2017).

The biggest reasons for food waste were that food was spoiled (28,6 %), best before date or use-by date had expired (21,1 %), too much was prepared (14,2%) and the uncertainty of eatability (12,7 %). Thus, almost two thirds of food waste was related to food spoilage or eatability quality. Proper handling of perishable products includes all steps from harvesting through processing and packaging to the consumer's freezer and fridge. All partners in the food chain are responsible for finding new solutions to tighten the lead time for food products from producer to the consumer.

This research emphasised that households independently of size are heterogeneous in attitude and behaviour. Twenty-five percent of the households, i.e. the upper quartile consisting of 106 households, produced 55.6 % of the avoidable food waste and the remaining seventy-five percent only 44.4 %. This study also revealed that some households with university students did not produce avoidable food waste at all. Also Knezevic et al. (2019) stated that there were various types of students. They found that university students need effective information on food waste to enable them to reduce their food waste (Knezevic et al., 2019). Various means to reduce avoidable food waste should be targeted to the 'heavy wasting' group. One way of improving good practices of university students would be sharing habits through peer learning i.e. from those student, who do not produce any or small amount avoidable food waste, to the heavy wasters.

Gabriel et al. (2021) insisted that awareness campaigns are useful, but this means should not be the only way to inform about food waste reduction. Each student group needs tailored information e.g., lectures, workshops and other types of dissemination (Gabriel et al., 2021; Knezevic et al., 2019; Principato et al., 2015). Food waste prevention is a cultural challenge that must be supported in studies e.g., at universities Leal Filho et al. (2021).

The wasting of food leads to negative monetary, environmental, and social impacts (van der Werf et al., 2021). People studying sustainability of food systems at universities should be given the tools to increase their awareness of food waste reduction. This study was conducted in two courses with several iterations. The main limit of this study was that there was no sampling method used. In the future, it would be valuable to research more accurate attitudes toward food waste and how those attitudes can be affected based on improved knowledge.

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Production and Evaluation of an Instant Maize-Soy Flour Enriched With Refractance Window Dried Jackfruit (*Artocarpus heterophyllus L.*) Powder

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Abstract

Porridge is a staple food in many developing countries and is usually used as a weaning or breakfast food. The increased preference for convenient and healthy meals has increased the desire for nutrient-enriched instant flours. Jackfruit is an underutilised fruit that is rich in vitamin C and other bioactive components. This study aimed to evaluate dried jackfruit powder as an ingredient for porridge flour. Formulations were made by substituting varying levels (0, 10, 20 and 30, 40 and 50%) of an extruded maize-soy blend (MSB) constituting 70% maize and 30% soy with refractance window dried jackfruit powder. The composite flours were used to make porridges which were analysed for their sensory acceptability by a 60-member semi-trained panel. The viscosity, water holding capacity, oil holding capacity, solubility index and bulk density of the flours were also assessed. Porridge acceptability, flour proximate composition, ascorbic acid and carotenoid content for the most preferred experimental formulation were compared to commercial maize-based instant flour and plain maize-soy instant flour. The most acceptable porridge was made from the 50% MSB and 50% jackfruit flour blend. The 50% jackfruit - MSB blend and control commercial instant flours attained drinking viscosity (2,500–3,000 cP) at 20% and 31% flour rates. The energy, protein, iron, calcium, β-carotene, and vitamin C densities of jackfruit - MSB porridge were 47.8 %, 48.9 %, 158.1 %, 226.5 %, 230.3 % and 125.9 % higher than those obtained from plain MSB porridge respectively. The results showed the potential of jackfruit as an ingredient for the nutritional enrichment of flours meant for making porridge.

Keywords: Refractance window drying technology; Jackfruit powder; Instant flours; Extrusion; Functional properties

1 Introduction

The jackfruit (*Artocarpus heterophyllus L.*) is a member of the Moraceae family. It is an underexploited tropical fruit crop (Williams & Haq, 2002). Jackfruit is widely cultivated in South and Southeast Asia, the Caribbean and Latin America and some parts of Africa, including Kenya and Uganda (Southampton Centre for Underutilised Crops, 2006). Jackfruit is the largest edible fruit and gives higher yields (150 to 180 fruits/tree) than any other fruit tree (Balamaze et al., 2019). Jackfruit provides an inexpensive, nutritious, edible bulb, rich in vitamins and minerals (Ranasinghe et al., 2019). Previous studies have revealed numerous health benefits of jackfruit including anticarcinogenic, antimicrobial, antifungal, anti-inflammatory, wound healing,

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Nomenclature

MSB	Maize-soy blend	RW	Refractance Window

and hypoglycaemic properties (Arora & Parle, 2016; Biworo et al., 2015; Ranasinghe et al., 2019). However, the fruit is highly perishable and considerable amounts, primarily obtained in the glut season, go to waste due to low market access and inappropriate post-harvest handling (Swami et al., 2016). Processing of jackfruit can extend shelf life, develop new food products, and contribute to income generation and employment (Swami et al., 2016). The use of jackfruit as an ingredient in widely consumed foods such as porridge flour would increase its consumption and consequently intake of vitamins and minerals. Drying specifically is an effective method for the production of shelf-stable food products or food ingredients. Refractance window (RW) drying is a simple, fast and inexpensive technology that gives products comparable in quality to freeze-dried products (Nindo & Tang, 2007). The production of jackfruit powder facilitates its use in different products such as instant soups, snacks, bakery, beverages, dairy, candy, ice cream, baby food, and pasta (Pua et al., 2007).

Porridges, usually prepared from cereals, are widely consumed in developing countries and are a convenient food for weaning infants and feeding the elderly and convalescents (Šimurina et al., 2018). Conventional porridges, however, have a long preparation time and very low energy and nutrient densities (Ejigui et al., 2007). Extrusion can produce instant flours, which are convenient for use as they do not need long preparation (Gandhi & Singh, 2015). Acceptability and nutritional attributes of porridges are frequently enhanced by added ingredients (Gandhi & Singh, 2015). Jackfruit has attractive characteristics such as excellent digestive and nutritive value (Pavan et al., 2014; Zhu et al., 2019), pleasant flavour, high palatability, and abundant availability during glut seasons, at a moderate price (Balamaze et al., 2019). The utilization of jackfruit for the preparation of instant flour has, however, not been explored. Hence, the present investigation was undertaken to determine the most acceptable jackfruit formulation for instant flour and determine the effect of adding jackfruit powder on the consumer acceptance, nutritional value and physical properties of a maize-soy blend instant flour.

2 Materials and Methods

2.1 Jackfruit powder preparation

Mature yellow-fleshed jackfruits were procured from Kayunga district, Uganda, in March 2021. Maturity was determined when the last leaf on the fruit stalk turned yellow, and the fruit skin colour became pale (Asia-Pacific Association of Agricultural Research Institution, 2012). The fruits were left to ripen under ambient conditions. The fruits were washed using potable water to remove foreign matter from the surface. The cleaned fruits were sectioned, and the arils and seeds separated. The arils were crushed in a food blender (Phillips Blender Model HR 1727, Koninklijke Philips N.V., Netherlands) at the highest speed (2) to produce a pulp. Blending was done intermittently for a total of three minutes. Refractance window drying was done using a hybrid batch scale refractance window dryer (Utility Model reference number UG/U/2020/000012) on a Mylar sheet (k-mac plastics-Type D clear, thickness 0.010 inches). Electricity was used as a source of heat energy to power the drying system. Uniform thickness of jackfruit pulp was achieved using specially fabricated slates that spread the puree on the top surface of the Mylar float at a thickness of 2.56 mm. The drying water temperature was 93^{o}C, and drying was for 60 minutes. The dry-

ing conditions were based on optimisation experiments done previously. After drying, the jackfruit flakes were scraped from the mylar sheet, ground into a powder using a mill (Phillips Model HR 1727, Koninklijke Philips N.V., Netherlands) and stored in resealable Ziplock bags placed in an airtight container in subdued light until further use.

2.2 Formulation and preparation of blends

A 70% maize to 30% soy blend was purchased from a local commercial supplier. The 70:30 cereal to legume ratio is recommended based on the lysine content of the ingredients (Ejigui et al., 2007) Control porridge was made from maize and soy flour without the addition of fruit powder. Experimental samples consisted of 5 levels (10, 20, 30, 40, and 50% (w/w) of substitution of MSB with jackfruit powder (Gandhi & Singh, 2015). Ingredients used in the instant porridge formulation were mixed by blending in a mill (Phillips Model HR 1727, Koninklijke Philips N.V., Netherlands) and sieved using a 600-micron sieve (Endecotts, UK) before being stored at room temperature in airtight, opaque Ziplock bags until analysis.

2.3 Chemical analysis

AOAC (2000) methods 925.09, 923.03, 962.09, AOAC 4.5.01 and 979.09 were used to determine moisture, ash, fibre, crude fat and crude protein content. The carbohydrate content (g) was estimated by difference (AOAC, 1995).

Total energy

The total energy (TE) value in kcal/100g of the three formulations was determined according to the method of (Kanu et al., 2009) using the formula shown in equation 1:

$$TE = (CARB \times 4) + (PROT \times 4) + (FAT \times 9) \quad (1)$$

Where CARB, PROT and FAT are the carbohydrate, protein and fat content in percentage. The percentage protein calories (PC) were determined as shown in equation 2:

$$PC = \frac{\%Protein \times 4}{TE} \quad (2)$$

(Kanu et al., 2009)

Mineral analysis

The Perkin-Elmer Corporation (1996) atomic absorption spectrometric (AAS) methods were employed to determine calcium, iron and zinc contents. The mineral concentrations were calculated using equation 3 below:

$$Ppm = \frac{\gamma \times V \times DF}{WT} \quad (3)$$

Where:
γ= the reading from the AAS at 422.7nm for Ca,213.9nm for Zn and 248.3nm for Fe
V= the volume to which the samples were brought,
DF= the dilution factor for those samples with concentrations beyond the calibration curve
WT= sample weight taken.

Vitamin C determination

Vitamin C content of the dried fruit product was determined by 2, 6-dichloroindophenol titrimetric method (Ugbe et al., 2017). Vitamin C content was expressed on a dry weight basis as mg/100 g sample using equation 4.

$$VitC = \frac{NTitr \times DCPIP_{eqv} \times V_{tot}}{V_{titr} \times W_s} \times 100 \quad (4)$$

Where VitC is the concentration in mg/100 g, NTitr is the Net titre value in ml $DCPIP_{eqv}$ are the equivalents of the DCPIP tritrating solution, V_{tot} is the total volume of the solution in ml, V_{titr} is the total volume used in the pippete and W_s is the sample weight in g.

Determination of total carotenoids

Total carotenoids in the flours were determined according to the method of Rodriguez-Amaya and Kimura (2004). The total carotenoid content

(TC) in $\mu g/g$ was calculated using the formula in equation 5:

$$TC = \frac{A \times V(ml) \times 10^4}{A^{1\%}_{1cm} \times p(g)} \quad (5)$$

Where A = Absorbance at 450nm; V = Total extract volume; p = sample weight; $A^{1\%}_{1cm} = 2592$ (β-carotene Extinction Coefficient in petroleum ether).

2.4 Determination of porridge nutrient density

Porridges were prepared with different flour rates (20-35%), and their viscosities were measured using a Brookfield DV II viscometer (Brookfield Engineering Labs, U.S.A.) using spindle R.V. no. 5 at 55°C. Flour rates that produced porridges of drinkable viscosities (2,500–3,000 cP) suitable for child feeding were recorded (Akande et al., 2017). Energy, protein, iron, zinc, calcium, β-carotene, and vitamin C densities (ND in $100ml^{-1}$) of the porridges with the desired viscosity (2,500–3,000 cP) were calculated using equation 6.

$$ND = \frac{Flourrate}{100ml} \times \frac{Nutrient}{100g} \quad (6)$$

2.5 Functional properties of composite flours

Water solubility index (WSI)

The WSI of the composite flour was determined using the method described by Kha et al. (2010) with some modifications. The WSI (%) was calculated as the percentage of dried supernatant with respect to the amount of the original 2.5 g jackfruit powder, as shown in equation 7.

$$WSI(\%) = \frac{Driedsupernatantweight}{Initialsampleweight} \times 100 \quad (7)$$

Water holding capacity

Water holding capacity (WHC) was determined according to Nguyen et al. (2015). Water holding capacity (g water/g of powder) was calculated as shown in equation 8.

$$WHC = \frac{Totalwatermass(g)}{Drymattermass(g)} \quad (8)$$

Oil holding capacity

Oil holding capacity (OHC) was calculated according to Nguyen et al. (2015). Oil holding capacity was calculated as shown in equation 9.

$$OHC = \frac{Massofsampleincludingheldoil(g)}{Massofdrymaterial(g)} \quad (9)$$

Bulk density

Bulk density was determined by the method of Chandra et al. (2015).

pH

The pH was determined according to the method by Amankwah et al. (2009).

2.6 Comparison of sensory properties of porridges made from different formulations of MSB-jackfruit powder

Five different porridge formulations (substitution with 10% - 50% jackfruit powder) were prepared by mixing 200 g of each composite flour in 800 ml of boiling water with constant stirring for about 4 minutes. Sensory acceptability was determined using the method by Akande et al. (2017) with slight modifications, using a semi-trained panel (n = 60) mainly comprised of students in the School of Food Technology, Nutrition, and Bioengineering, Makerere University. A 9-point hedonic scale was used with 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. The most acceptable MSB-jackfruit formulation was evaluated with a commercial instant porridge and the control porridge. Acceptability of the composite jackfruit porridge was compared with a commercial maize-based instant porridge commonly consumed in Kampala city, Uganda. Similarly, a 9-point hedonic scale was used with

1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.

2.7 Statistical analysis

The results are reported as mean values±standard deviations of three independent determinations. Results obtained were subjected to statistical Analysis of Variance (ANOVA) using XLSTAT software version 2019 to determine variation between means. Tukey's HSD test was conducted to analyse differences between means at a 95% confidence interval.

3 Results and Discussion

3.1 Comparison of sensory properties of porridges made from different formulations of MSB-jackfruit powder

There were significant differences ($p<0.05$) in appearance, taste, mouthfeel and overall acceptability of the five formulations evaluated (Table 1). From the results, the superior overall acceptability of the 50% formulation could be associated with the sweet taste imparted by the jackfruit powder and the appearance of the porridge. The formulation with 50% jackfruit powder was selected for comparison with the control and a commercial sample.

3.2 Proximate and mineral composition of commercial and jackfruit composite flours

The proximate chemical composition of the three formulations, the commercial flour, 50% jackfruit flour and plain maize-soy flour, are presented in Table 2 . The moisture content of the flours ranged from 6.3 % to 8.1%, which was within the range required for flours to be shelf-stable (Ntuli et al., 2013). Moisture content directly influences the stability of flours during storage, mainly because micro-organisms naturally occurring in the flour would readily thrive at high moisture content, causing deterioration during storage. The protein content for the commercial and formulated composite formulation was significantly different ($p<0.05$) from the plain MSB flour. The plain MSB flour had the highest protein content, which can be attributed to the higher proportion of soy flour in the formulation. The protein contents for all the flours were above 8% dry weight, indicating good quality flour (Ntuli et al., 2013). Carbohydrate content for the three formulations ranged from 75.7% to 81.32%, with the three formulations being significantly different ($p<0.05$) from each other. The commercial and formulated samples were within the range (70-96%) of results reported by Makame et al. (2020) for the nutritive value of common African indigenous/local complementary porridge samples. The high carbohydrate content of the formulations is attributable to the high carbohydrate content of maize which was the principal ingredient in the formulations, and the high carbohydrate content of the fruit powder added to the MSB. The high carbohydrate content of the jackfruit formulation in this study could be advantageous, especially to infants, as the fruit sugars impart more sweetness to the porridge, thereby enabling children to take more of the food per feeding and minimize the addition of table sugar during the preparation of the porridge.

The addition of jackfruit powder significantly ($p<0.05$) increased the fibre and ash contents of the porridge. Consumer interest in dietary fibre has grown significantly in recent years. Several studies link increased fibre intake to reduced risks of cancer and cardiovascular diseases, digestive health benefits, and weight management (Barber et al., 2020). The blend with 50% jackfruit powder showed higher amounts of dietary fibre (4.1%) than the plain maize and soya (2.7%) and the commercial flour samples (2.8%). Porridge flour supplemented with up to 50% jackfruit powder, with 4.1 g of fibre per 100 g of food, could be labelled as a 'source of fibre' according to Codex Alimentarius (1997), which has established that for solid food to be considered a 'source of fibre' it should present at least 3 g of fibre for each 100 g of food. This confirms that jackfruit maize-soy blends in a 50: 50 ratio would be potential sources of fibre in food preparations. The 50% jackfruit MSB formulation had the highest ash content, indicating an

Table 1: Consumer acceptability scores of porridges prepared from different formulations of jackfruit composite flours

Parameter	**10%**	**20%**	**30%**	**40%**	**50%**
Appearance	6.0 ± 1.67^{ab}	5.9 ± 1.46^{a}	6.0 ± 1.40^{ab}	6.5 ± 1.55^{b}	6.8 ± 1.67^{bc}
Aroma	6.4 ± 1.71^{a}	6.2 ± 1.67^{a}	5.8 ± 1.63^{a}	6.1 ± 1.56^{a}	6.0 ± 1.98^{a}
Taste	5.5 ± 2.00^{a}	5.4 ± 1.67^{a}	5.4 ± 1.90^{a}	5.9 ± 1.80^{ab}	6.2 ± 1.89^{b}
Mouth feel	5.5 ± 2.07^{ab}	5.6 ± 1.65^{ab}	5.6 ± 1.77^{a}	6.0 ± 1.78^{ab}	6.3 ± 1.86^{bc}
General acceptability	6.0 ± 1.70^{ade}	5.9 ± 1.30^{a}	5.7 ± 1.42^{a}	6.4 ± 1.62^{bde}	6.6 ± 1.75^{bc}

Values show mean±SD (n = 60). Figures in the same row with the same superscript are not significantly ($p > 0.05$) different. A 9-point hedonic scale was used with 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.

improvement in the total mineral contents due to substitution with jackfruit powder (Mandha et al., 2021). The addition of jackfruit powder increased the carotenoids content of the flour. The 50% jackfruit powder blend was highest in carotenoid content (346.5 μg/100 g), whereas the plain maize and soya bean blend was the lowest (142.1 μg/100 g). Similarly, the addition of jackfruit powder increased the ascorbic acid content, with the 50% jackfruit formulation containing 27.247 mg/100 g compared to the plain maize soya bean blend (17.814 mg/100 g).

The energy density of the porridges was in the range of 379 to 397 kcal/100g, with a significant difference ($p<0.05$) among the values. According to the Codex standard for processed cereal-based foods for infants and young children (CODEX STAN 074-1981, 2006), the energy density of a cereal-based complementary food should be ≥ 80 kcal/100g. The formulated porridge considerably surpassed the minimum stipulated daily energy requirement for infants up to 12 months.

The 0% and 50% formulations were rich in calcium, followed by iron, with the 0% having the highest ($p<0.05$) amount of the two minerals. The high amount of calcium and iron observed for the 0% formulation could be attributed to its higher content of soya (Tenagashaw et al., 2017).

3.3 Functional properties of jackfruit blends

The functional properties of jackfruit composite flours (Table 3) showed that the substitution of the maize-soy flour with jackfruit powder in the blends led to decreased water holding capacity (from 3.76 to 2.75 g water/ g sample), oil holding capacity (1.96 to 1.62 g water/ g sample), bulk density and pH (6.717 to 5.467).

WSI values for the formulations ranged between 26.91% and 46.12%. The highest WSI was observed in the 50% jackfruit formulation. The high WSI of the jackfruit formulations in this study can be explained by the quantity of soluble molecules (e.g. sugars and possibly soluble fibre). The relatively high WSI of formulations with higher jackfruit powder substitution ratios may suggest easier digestibility of the porridges, which is desired for infant feeding (Amagloh et al., 2013; Awuchi et al., 2019). The lower solubility of the commercial flour and 0% formulations could be due to the slightly higher starch content Amagloh et al. (2013). These findings are consistent with the findings of Gandhi and Singh (2015), who established that an increase in the level of fruit pulp in instant porridge formulations showed an increasing trend of water solubility index with a significant increase observed beyond 10% guava pulp. Higher values for water solubility index were recorded at 40–50% fruit pulp.

Table 2: Proximate and mineral composition of commercial and jackfruit composite flours

	Commercial sample	**0%**	**50%**
Moisture (%)	8.14±0.05^{b}	6.66±0.10^{a}	6.31±0.29^{a}
Fibre (%)	2.85±0.37^{a}	2.67±0.37^{a}	4.09±0.27^{b}
Ash (%)	1.41±0.04^{a}	1.99±0.04^{b}	2.59±0.08^{c}
Fat (%)	2.99±0.13^{b}	2.45±0.44^{ab}	1.24±0.12^{a}
Protein (%)	11.43±0.30^{a}	17.18±0.69^{b}	10.99±1.32^{a}
Carbohydrate (%)	81.33±0.71^{b}	75.70±1.48^{a}	81.09±1.61^{c}
Energy (kcal/100 g)	397.91±0.92^{b}	393.64±1.66^{b}	379.22±1.68^{a}
% protein calories	12.51±0.38^{a}	18.71±0.84^{b}	12.36±1.63^{a}
Carotenoids (µg/100 g)	162.4±0.16^{a}	142.1±0.21^{a}	346.5±0.18^{b}
Ascorbic acid (mg/100 g)	18.69±0.28^{b}	17.81±0.10^{a}	27.25±0.20^{c}
Fe (mg/100g)	13.61±0.09^{a}	36.59±0.09^{c}	22.64±0.08^{b}
Zn (mg/100g)	1.09±0.08^{b}	0.86±0.00^{ab}	0.57±0.01^{a}
Ca (mg/100g)	25.69±0.06^{a}	67.08±0.08^{c}	54.12±0.02^{b}

Values show mean±SD. Figures in the same row with the same superscript were not significantly (p >0 .05) different.

Table 3: Water holding capacity, oil holding capacity, bulk density, solubility index and pH of commercial and jackfruit composite flours

	WHC(g/ml)	**OHC (g oil/g)**	**BD (g/cc)**	**SI (%)**	**pH**
Com	3.84±0.03^{b}	1.23±0.08^{a}	0.41±0.01^{a}	11.50±1.04^{a}	6.437^{e}
0%	3.76±0.04^{b}	1.96±0.02^{b}	0.49±0.01^{ab}	26.91±0.20^{b}	6.717^{f}
10%	3.72±0.10^{b}	1.98±0.01^{b}	0.49±0.01^{ab}	28.61±0.71^{b}	6.393^{d}
20%	3.61±0.09^{b}	1.95±0.02^{b}	0.51±0.03^{b}	36.24±0.82^{c}	6.080^{c}
30%	3.42±0.09^{b}	1.87±0.06^{b}	0.51±0.01^{b}	42.09±0.90^{d}	5.930^{b}
40%	3.17±0.28^{ab}	1.86±0.04^{b}	0.51±0.01^{b}	42.09±0.88^{d}	6.137^{c}
50%	2.75±0.07^{a}	1.62±0.06^{ab}	0.49±0.02^{ab}	46.12±0.19^{d}	5.467^{a}

Values show mean±S.D. Figures in the same row with the same superscript were not significantly (p > 0.05) different. Com: Commercial sample, W.H.C.: Water holding capacity, O.H.C.: Oil holding capacity, BD: Bulk density, SI: Solubility index

Bulk density

Bulk density measures the heaviness of a flour sample and can be used to determine its packaging requirements (Kraithong et al., 2018). There were no significant differences in the bulk densities ($p>0.05$) amongst the composite flours with jackfruit powder added. However, the bulk density of the commercial flour was significantly lower than that of the composite flours with jackfruit powder. Bulk density ranged from 0.41 to 0.51 g/ml. The results obtained for the bulk density were slightly higher than the value reported by Yusufu et al. (2013) for complementary food consisting of sorghum, African yam bean and mango (0.42 g/cm^3). A higher bulk density is undesirable in the packaging of foods because it results in a large oxygen reservoir (Otegbayo et al., 2013).

Oil holding capacity

Oil holding capacity is an important functional property as it plays a vital role in enhancing the mouthfeel and retaining the flavour of foods. According to Grigelmo-Miguel et al. (1999), ingredients with a high OHC allow the stabilisation of high-fat food products and emulsions. The oil holding capacity of the composite flours ranged from 1.62-1.96 g oil /g of sample. While there were no significant differences in the oil holding capacities ($p>0.05$) amongst the composite flours with jackfruit powder added, there was a significant difference between the commercial flour sample and the composite flour samples. This property is mainly affected by protein content in the sample, where the side chains of non-polar amino acids can form hydrophobic interactions with hydrocarbon chains of lipid (Jitngarmkusol et al., 2008). According to Keskin et al. (2022), fibre composition also affects the oil holding capacity of food products.

Water holding capacity

Water holding capacity decreased considerably as the percentage of fruit powder increased. This may be attributed to the relative decrease in starch content with the addition of fruit powder and competition of absorption of water between the fruit powder and available starch. This result is in agreement with those of Gandhi and Singh (2015). They reported a decrease in the water holding capacity when the ratio of fibre/maize starch increased in the extrusion of maize fibre and maize starch blend. According to Ajanaku et al. (2012), a low water holding capacity aids digestibility of the food in the alimentary canal of children suggesting the potential use of the 50% jackfruit composite porridge as a weaning food to improve the nutritional and health status of growing infants.

pH levels

The addition of jackfruit powder significantly affected the pH in the composite porridges. A significant decrease in pH was observed in composite porridges due to blend formulation (Table 3). The control porridge (100% maize-soy blend) had a higher pH (6.717) than the MSB-jackfruit composite porridges, with pH values of 6.3 to 5.4. Similarly, Ngadze et al. (2019) observed a drop in pH with the addition of monkey orange to a staple maize porridge.

3.4 Viscosity analysis of the jackfruit and commercial instant porridges

Viscosity influences nutrient intake because it contributes to an increase or decrease in the bulk of a product (Mburu et al., 2011). The high viscosity and low energy density of food make it difficult for an individual to consume enough of that food to meet the nutritional requirements. Porridge with a high flour rate is usually more energy and nutrient-dense than those with lower flour content. However, the high viscosity of porridges with high flour content make consumption difficult, especially for young children. Nout (1993) recommends that weaning porridges should have approximately 20% dry matter content. The jackfruit and control commercial instant porridges attained the drinking viscosity (2,500–3,000 cP) at 20% (20 g/100 ml) and 31% (31 g/100 ml) flour rates, respectively (Fig. 1 and Fig. 2). Porridge viscosity of 1000—3000 cps is soup-like and easily spoonable, making it

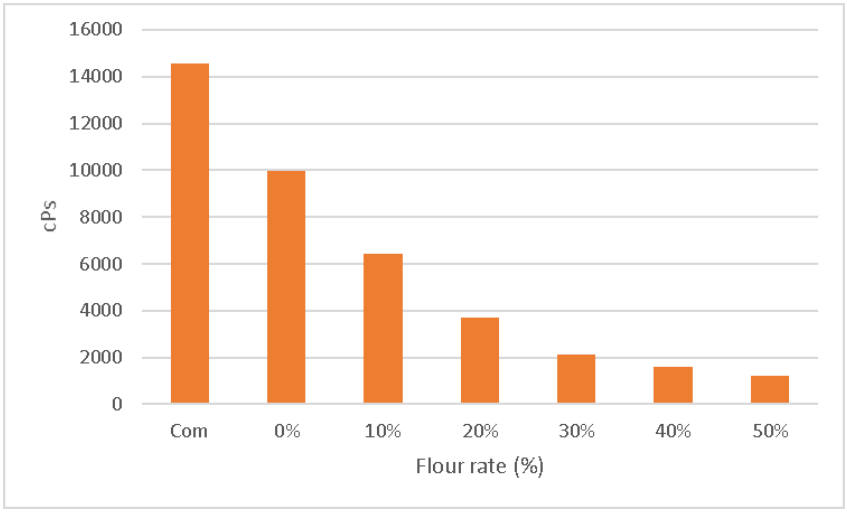

Figure 1: Viscosity of different jackfruit porridge formulations at 25% flour rate; Com: Commercial composite flour

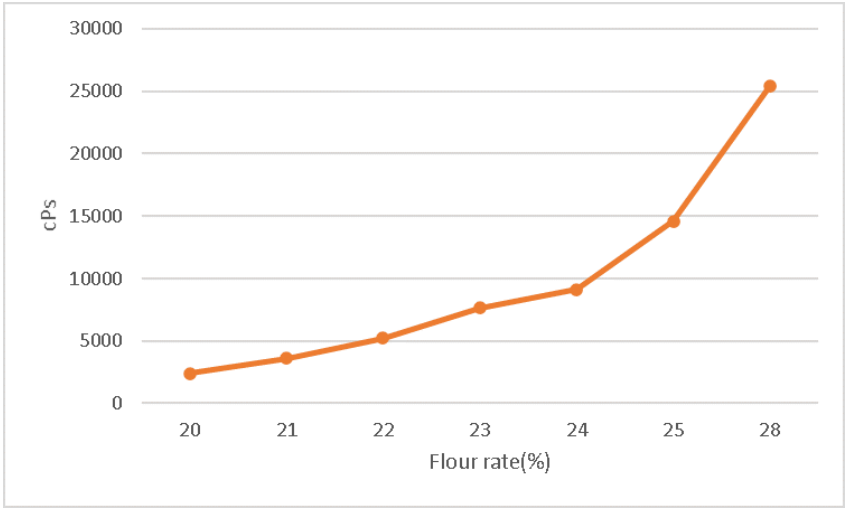

Figure 2: Viscosity of commercial porridge at different flour rates

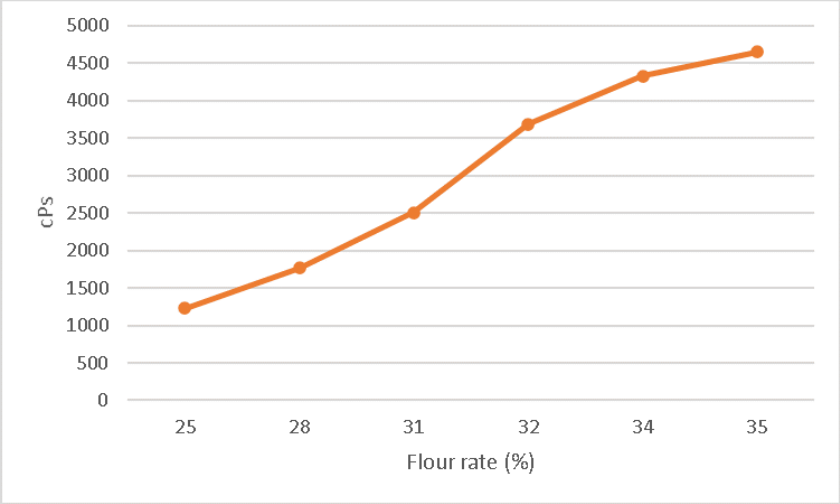

Figure 3: Viscosity of 50% jackfruit porridge at different flour rates

especially appropriate for infant feeding (Oladiran & Emmambux, 2022). The viscosity of the porridges was significantly reduced by the addition of jackfruit powder (Fig. 3). This is because, at higher concentrations of maize-soy blend flour, there are more starch granules to interfere with the flow properties of the porridge, hence increasing the viscosity. These findings were consistent with Mandha et al. (2021) who found that the addition of mango flour decreased the viscosity of the porridge. Benefits of the reduced viscosity are increased total energy and nutrient intakes, greater ease of feeding, the consequent reduction in feeding times, and increased digestibility of the foods (World Health Organization, 1998).

Nutrient density of the jackfruit porridge

Table 4 shows the nutrient densities of the jackfruit and commercial porridges at 31% and 20% flour rates, respectively. The energy, protein, iron, calcium, β-carotene and vitamin C densities of the jackfruit composite instant flours were higher than that of the maize-soy instant porridge. However, the zinc density of the jackfruit composite instant porridge was lower than that of the commercial maize-soy instant porridge. The percentage of soya bean flour in the commercial maize-soy instant porridge could have accounted for its higher zinc density. The high nutrient densities of the jackfruit composite instant porridge indicated its suitability for infant and young child feeding and could help reduce protein-energy malnutrition and micronutrient deficiencies.

Sensory evaluation

The mean acceptability scores for all attributes ranged from 5.8 to 6.6 for the commercial porridge, 5.3-6.7 for the 0% jackfruit porridge and 6.2–7.0 for the jackfruit composite porridge (Table 5). There were no significant differences among the three porridges in sensory attributes except for taste, mouthfeel, consistency and overall acceptability. The flavour of the porridge prepared with 50% jackfruit powder was most preferred ($p<0.05$). The mean overall acceptability score for 50% jackfruit porridge was significantly ($p<0.05$) higher than that for the plain MSB (0% jackfruit powder) porridge. The inclusion of jackfruit powder in instant porridge resulted in a product with a sweeter taste and smoother consistency which was most likely responsible for higher taste and consistency scores.

Table 4: Calculated nutrient density (per 100 ml) of the porridges

Nutrient	Jackfruit instant porridge (31 g/100 ml)	Maize and soy instant porridge (20 g/100 ml)
Energy (kcal)	117.64	79.58
Protein (g)	3.41	2.29
Iron (mg)	7.02	2.72
Zinc (mg)	0.18	0.22
Calcium(mg)	16.78	5.14
B-carotene (μg)	8.95	2.71
Vitamin C (mg)	8.45	3.74

Table 5: Comparison of sensory acceptability scores for plain porridge, jackfruit composite porridge and a commercial instant soy porridge

	Sample code		
Attribute	**Commercial**	**0%**	**50%**
Appearance	6.6 ± 1.43^{a}	6.2 ± 1.68^{a}	6.7 ± 2.02^{a}
Aroma	6.4 ± 1.51^{a}	6.7 ± 1.69^{a}	6.2 ± 2.07^{a}
Taste	5.8 ± 1.87^{a}	5.3 ± 1.87^{a}	6.9 ± 1.76^{b}
Mouthfeel	6.2 ± 1.87^{ab}	5.7 ± 2.11^{a}	6.9 ± 1.50^{b}
Consistency	6.3 ± 1.86^{b}	5.4 ± 1.86^{a}	6.5 ± 1.78^{b}
General acceptability	6.4 ± 1.61^{ab}	5.9 ± 1.63^{a}	7.0 ± 1.55^{b}

Values show mean ± SD (n = 62). Figures in the same row with the same superscript were not significantly ($p > 0.05$) different. A 9-point hedonic scale was used with 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely.

4 Conclusions

The study demonstrated that refractance window dried jackfruit powder could be used as an ingredient for maize-soy flour blends to improve their nutritional and sensory attributes. Addition of jackfruit powder increased the fibre, ash, carbohydrate, carotenoids and ascorbic acid contents of the flour. The jackfruit enriched the energy content of the flour, and protein, iron and calcium densities were higher than that of the plain maize-soy flour, the latter being more acceptable in terms of its sensory characteristics. Furthermore, replacing 50% of maize-soy flour with jackfruit powder resulted in a significant reduction in the viscosity, thus making it appropriate as a weaning food. A porridge with low viscosity but with high energy density is desirable for infants and young children for easy mastication and swallowing. The porridge also met the nutritional requirements of infants and preschool children. Therefore, it can be recommended as a sustainable supplementary food source to improve vulnerable populations' nutritional status and health.

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Effect of Fermentation Time on Nutrition Content, Physical Properties, pH, Amino Acids, Fatty Acids Composition and Organoleptics on Fermented Mackerel Sausage (*Rastrelliger kanagurta* Cuvier) Characteristics

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Abstract

Fermentation increases the functional value of food. During fermentation, chemical changes occur in organic substrates, such as carbohydrates, proteins, and fats due to enzyme activities of microorganisms. Functional foods containing unsaturated fatty acids are an alternative for preventing cardiovascular disease. The Indian mackerel (*Rastrelliger kanagurta* Cuvier) is rich in protein, polyunsaturated fatty acids, and non-essential and essential amino acids. Fish that are processed into sausage and fermented can be used as an alternative functional food to prevent cardiovascular disease. This study analysed the effect of fermentation time on nutritional content (carbohydrate, protein, fat, water, ash, amino acid, and fatty acid contents), physical properties, pH, and organoleptic properties in fermented mackerel sausage. This was a completely randomized experimental study with three fermentation times of 1, 2, and 3 days, and 0 days as a control. Fermentation was carried out spontaneously with 1.9% salt and sugar without adding a bacterial culture. The drying temperature was 50^{o}C for 3 hours, and the fermentation temperature was 35^{o}C. The fermentation duration of mackerel sausage affected the nutritional contents (carbohydrates, protein, fat, water, ash, amino acids, and fatty acids), physical properties (hardness and chewiness), pH, and organoleptic properties (colour, aroma, taste, and texture). Overall, the longer the fermentation time, the higher the carbohydrate, protein, fat, total ash content, total amino acid, total fatty acid, hardness and decreased organoleptic (colour, aroma, taste, texture), elasticity, and water contents. The best formulation for fermented mackerel sausage was 1 day of fermentation time.

Keywords: Indian mackerel (*Rastrelliger kanagurta* Cuvier); Sausage; Nutritional content; Physical properties; Organoleptic; Fermentation time

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1 Introduction

Cardiovascular disease (CVD) is a major contributor to global morbidity and mortality (Murray et al., 2012). CVD describes a combination of several diseases that attack the blood vessels and heart. One of the manifestations of CVD is coronary heart disease (CHD), which occurs due to hardening or atherosclerosis of the coronary arteries resulting in a decrease of blood supply to the heart muscle (Frak et al., 2022). In 2016, nearly 30% of the world's population or about 17.9 million people died from CVD; 85% of these deaths were due to heart attacks and strokes. According to the results of Basic Health Research in 2018, almost 1.5% of Indonesia's population was diagnosed with heart disease, and Central Java Province was fourth overall with a prevalence of 1.4% (Indonesia Basic Health Research, 2018).

Diet plays an important role in reducing the prevalence of CVD. Consumption of cardioprotective food groups and adequate and regular exercise help prevent heart disease (Casas et al., 2018; Jung et al., 2018). Cardioprotective foods included those high in fibre, antioxidants, vitamins, minerals, polyphenols, monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) (Casas et al., 2018; Jung et al., 2018). One food alternative that contains low saturated fat and high protein is found in locally based foods, such as fish. Indian mackerel (*Rastrelliger kanagurta* Cuvier) is an easily available food source that is priced relatively inexpensively compared to other marine fish. Mackerel is usually prepared by frying. However, this is considered a poor method for CHD sufferers because frying forms trans-fats, which can increase the risk of CHD.

Fish is a perishable food. Thus, an alternative to processing mackerel is to prepare sausage. Sausages are made from processed meat that is crushed and preserved by salting (Mohan, 2014). Processed red meat in sausage contains high levels of saturated fatty acids (SFA) that can cause blockage of blood vessels or atherosclerosis (Ragino et al., 2019). Mackerel is rich in PUFA contents, such as omega-3 fatty acids, eicosapentaenoic acid, and docosahexaenoic acid (Marichamy et al., 2009; Sonavane et al., 2017). Regular consumption of these fats can reduce the progression of plaque formation in the arteries (Bäck, 2017). In addition, fish protein is composed of complete types of non-essential and essential amino acids. Amino acids repair damaged tissue, protect the liver from toxic substances, lower blood pressure, and regulate cholesterol metabolism (Hoffer, 2016; Nurjanah et al., 2015).

One of the traditional methods of preserving meat is fermentation of meat products that used for improving safety, shelf life, organoleptic, and nutritional attributes (Lazic et al., 2019). Fermented sausage is smoked with liquid smoke before being incubated or fermented at 35^{o}C. This smoking method helps the sausage to become drier, thereby extending shelf life. In addition, fermentation increases the functional value of the food. During fermentation, proteolytic enzymes degrade proteins into amino acids and peptides, while lipolytic enzymes hydrolyse fats to become free fatty acids (Bou et al., 2017; Juturu & Wu, 2016). According to previous research, free amino acids, such as leucine, valine, and lysine, increase during fermentation (Bou et al., 2017). In addition, the lactic acid produced during fermentation sharpens and strengthens the taste of the sausage so that it forms a sour taste and a decrease in pH, which causes protein coagulation and a hard texture as a characteristic of fermented sausage (Mohan, 2014). Therefore, fermented sausage is a source of processed meat that has the potential to become a functional food. Functional foods contain unsaturated fatty acids (UFA), such as PUFAs and MUFAs, and are an alternative food that prevents CVD (Damanik et al., 2018). The fermented fish and their health benefit, as well as the contribution of microorganism that produces many nutrition element with higher bioavailability linked with several beneficial properties (Zang et al., 2020).

Fermentation time affects the quality of the product because fermentation changes the chemical composition and physical properties of the product. In this study, the selected fermentation times were 0, 1, 2, and 3 days. The choice of fermentation times was based on a study reporting that 1 day of fermentation is the optimal duration. Thus, we were interested in conducting research on the nutritional content, physical properties, pH, and organoleptic properties of

fermented mackerel sausage as a functional food product that can be used as an alternative to prevent CHD based on variations in fermentation time (Xiong & Mikel, 2001).

2 Materials and Methods

A completely randomized experimental study was performed using four fermentation times, consisting of control (0 day), 1, 2, and 3 days for the fermented mackerel sausage. The variables were tested at the Diponegoro University Nutrition Science Laboratory, UPT Integrated Laboratory of Diponegoro University, Bogor Saraswanti Laboratory, and the Fishery Product Quality Testing and Application Center (BP2MHP/Badan Pengujian dan Penerapan Mutu Hasil Perikanan).

2.1 Preparation of the Fermented Mackerel Sausage Samples

The fresh mackerel flesh was purchased from Rejomulyo fish market, Semarang City, Central Java, Indonesia. The raw materials for preparing the fermented mackerel sausage consisted of 48% of the total weight of mackerel, 1.9% salt and sugar, 14.6% tapioca flour, 9.7% corn oil, 1.5% garlic and onion, 14.6% ice, 2% lime, 3.8% egg white, 15% carrageenan flour, liquid smoke, and sausage sleeve. Commercial salt, sugar, tapioca flour, corn oil, garlic, onion, lime, egg white, and carrageenan flour were obtained from TBK Fortune, Semarang City. The liquid smoke was produced by Fronthea from Diponegoro University (Swastawati et al., 2019). The sausage casing was purchased from Harmony mart, Semarang City. The mackerel sausage was prepared in three stages. Stage 1 included the manufacturing of the fermented mackerel sausage, mixing all raw material sequentially and pouring into an edible sausage casing; stage 2 was smoking the mackerel sausage by soaking it in a 5% liquid smoke solution for 30 min at a set temperature of $\pm$ 10^{o}C. The mackerel sausage was subsequently placed in an oven at 50^{o}C for 3 hours; and stage 3 was the fermentation process from day 0 to day 3 in an incubator at 35^{o}C. Fermentation was carried out spontaneously with no bacterial culture.

2.2 Proximate Analysis, Physical Properties, and pH

Testing of the physical properties and pH was carried out at UPT Integrated Laboratory of Diponegoro University. Testing of fat, protein, water, and ash contents was carried out at the Fishery Product Quality Testing and Application Center (BP2MHP/Badan Pengujian dan Penerapan Mutu Hasil Perikanan) Semarang. All analyses were performed in triplicate. Protein content was analysed by the Kjeldahl method (Magomya et al., 2014). Fat content was determined using the Soxhlet method (Zarnowski & Suzuki, 2004). Analysis of water content used the oven-drying method. Ash content was determined by heating samples of sausage at 550 ^{o}C for 5 hours in a muffle furnace and weighing the resultant ash. The carbohydrate content analysis was determined by difference (AOAC International., 2006). The pH was measured using a digital pH meter (pH meter TPX-90i Chemical Laboratories Co., Ltd). The physical properties were determined using a Brookfield CT3^{TM} texture analyser (Brookfield Inc, USA). The optimal treatment formulation was decided using the de Garmo method (DeGarmo et al., 1993).

2.3 Analysis of Amino Acid and Fatty Acid Composition

The analysis of the fatty acid composition was carried out using gas chromatography (GC) in duplicate at the Saraswanti Laboratory, Bogor. The GC analyses were performed on 7890A Gas Chromatography System (Agilent Technologies, California, US) equipped with flame ionization detector and splitless injector (1 μL). Injector and detector temperature were set at 270 ^{o}C and 280 ^{o}C, respectively. The column used was a DB-23 (60 m $\times$ 0.25 mm, with film thickness of 0.25 μm)(J and W Scientific, Folsom, CA). The GC oven program was as follows: 130 ^{o}C (hold 2 min), to 170 ^{o}C at 6.5 ^{o}C /min (hold 5 min), to 215 ^{o}C at 2.75 ^{o}C/min (hold 12 min), to 230 ^{o}C at 30 ^{o}C/min (hold 30 min). Helium and nitrogen of ultrahigh purity grade were used as carrier gases at flow rates of 11.07 and 31.24 mL/min. Fatty acid identification

was determined by comparing retention time of the peaks with the respective external standards. The concentration of fatty acids was calculated with the following equation from AOAC 996.06 (AOAC International, 2002). Five fatty acids were analysed based on the double-bond group, such as saturated fatty acids (SFA), polyunsaturated fatty acids (PUFAs), monounsaturated fatty acids (MUFAs), unsaturated fatty acids (UFA), and omega-3 fatty acids. The percentages of saturated, unsaturated, monounsaturated, and polyunsaturated fatty acid were calculated as follows using Eqs.1-4:

$$SFA(\%) = \sum \text{SFA injection}(\%) \times \text{fatty acid}(\%) \quad (1)$$

$$UFA(\%) = \sum \text{UFA injection}(\%) \times \text{fatty acid}(\%) \quad (2)$$

$$MUFA(\%) = \sum \text{MUFA injection}(\%) \times \text{fatty acid}(\%) \quad (3)$$

$$PUFA(\%) = \sum \text{PUFA injection}(\%) \times \text{fatty acid}(\%) \quad (4)$$

The amino acid composition was determined by high performance liquid chromatography (HPLC) in duplicate at the Saraswanti Laboratory Bogor, using a Shimadzu CBM 20A chromatograph. Fifty milligrams of dried sample were placed in a test tube with ground glass stopper and mixed with 5 mL of citrate phosphate buffer (pH 4.6) containing 10 mg β-glucosidase (37 units). The sample was hydrolysed at 37^{o}C for 4 h, and 5 mL of ethanol was added. After centrifugation for 10 min, 8 mL of the supernatant was dried in a vacuum evaporator. The compounds were identified by retention times and spectra in comparison with standards and quantified by the peak area. Fifteen amino acids were analysed; 8 of 15 were the essential amino acids histidine, threonine, leucine, lysine, arginine, valine, isoleucine, and phenylalanine, whereas the remaining seven were non-essential amino acids proline, tyrosine, glycine, alanine, aspartic acid, glutamic acid, and serine. Amino acid requirements were calculated based on the recommendations of the World Health Organization (WHO) for each group, as shown in Table 1 (World Health Organization et al., 2007).

2.4 Organoleptic Testing

Organoleptic testing was carried out by semi-trained panellists consisting of 30 students from the Department of Nutrition Science Diponegoro University, who agreed and signed informed consent. The organoleptic testing was conducted compliance with all regulations and confirmation that informed consent was obtained. Attributes tested were colour, taste, aroma, and texture. The evaluation of the hedonic test was categorized into a scale of 1 to 4 (1= really dislike, 2 = dislike, 3 = like, 4 = really like).

2.5 Data Analysis

The data analysis was performed using SPSS statistics software 25.0 for Windows (IBM, Chicago, IL, USA). The normality of the data was tested using the Shapiro-Wilk test because the data were <50. Analysis of the proximate data, physical properties, pH, and organoleptic properties was by analysis of variance (ANOVA) and the Kruskal-Wallis test followed by the Bonferroni and Mann-Whitney tests. ANOVA and the Kruskal-Wallis test were performed for the amino acid and fatty acid analyses followed by the Games-Howell post hoc test. A P-value $\leq$ 0.05 was considered significant.

3 Results and Discussion

3.1 Proximate Composition

Mackerel sausage fermented for 3 days had the highest fat, protein, ash, and carbohydrate contents compared to the other treatments. In contrast, mackerel sausage fermented for 3 days had the lowest water content compared to the other treatments. Significant differences in the contents of fat, protein, water, ash, and carbohydrate were observed in mackerel sausage fermented for different durations, as shown in Table 2.

A significant difference in fat content was observed corresponding to the number of days of fermentation. The fish sausage contained 3.37% fat on day 0. Fat content increased to 4.41% after 3 days of fermentation. This was in accor-

Table 1: Amino Acid Requirements

Amino Acid	Requirements	
	mg/g protein/day	mg/kg weight/day
Histidine	15	10
Isoleucine	30	20
Leucine	59	39
Lysine	45	30
Methionine	16	10
Phenylalanine + Tyrosine	38	25
Threonine	23	15
Valine	39	26

dance with SNI 7755: 2013, which states that the maximum fat content in fish sausage should be 7.0%. The increase in fatty acids was due to secondary lipolytic activity of lactic acid bacteria (LAB), which actively release fatty acids from fat molecules during fermentation (Raveschot et al., 2018).

The fermented mackerel sausages contained 15.34% protein before fermentation (control day/day 0), and increased to 33.91% after 3 days of fermentation. This was in accordance with SNI 7755: 2013, which states that fish sausage should contain at least 9.0% protein. This increase in protein was due to the increased level of total nitrogen in the fermented mackerel sausage and an increase in the population of LAB. The increase in nitrogen was caused by LAB proteases, which actively breakdown protein into amino acids and peptides, resulting in an increase in nitrogen and protein (Raveschot et al., 2018).

The water content in the fermented mackerel sausage varied depending on the fermentation duration. The water content, which ranged from 65.32 to 22.49% of the total nutrition component, gradually decreased from days 0 to 3 of fermentation. This result was due to the raw materials added as well as evaporation during the smoking and fermentation processes, which dried out the surface of the sausage (Savijoki et al., 2006). The maximum water content of fish sausage should be 68.0% according to SNI 7755: 2013. The results of this study were in accordance with this value, as total water content in mackerel sausage prior to fermentation (0 day/control) was 65.32%. Before fermentation, some water molecules form hydrates with other molecules (oxygen, nitrogen, carbohydrates, protein, and other organic compounds) so that the water turns into free water. The free water will evaporate significantly due to enzyme activity breaking bonds of water into free water during the fermentation processes.

The ash content of the mackerel sausage was significantly different during the 3 days of fermentation. Ash content indicates the presence of minerals in food; the higher the ash content, the higher the level of minerals in the food. Ash content increased after the third day of fermentation compared to day 0 due to the accumulation of minerals in the product during fermentation. Not all minerals are burned during the ashing process; thus, ash accumulates in the product (De Vuyst & Vandamme, 1994). The maximum ash content of fish sausage should be 2.5%, according to SNI 7755:2013. This percentage is in accordance with the results of this study, as total ash content in mackerel sausage prior to fermentation (0 day/control) was 2.05%.

3.2 Amino Acid Composition

The main amino acids in mackerel were glutamic acid, aspartic acid, and lysine. Glutamic acid was the most plentiful non-essential amino acid in mackerel at 3,583.73 mg/100 g, while the es-

Table 2: Proximate analysis of the fermented mackerel sausages

Formula	(Mean ± Standard Deviation) (%) n = 3				
	Fat Content	Protein Content	Water Content	Ash Content	Carbohydrate
F0	3.37 ± 0.03	15.34 ± 0.30	65.32 ± 0.14	2.05 ± 0.02	13.91 ± 0.48
F1	3.55 ± 0.02	20.62 ± 0.28	53.79 ± 0.50	2.84 ± 0.02	19.18 ± 0.81
F2	4.20 ± 0.03	31.97 ± 0.60	34.83 ± 0.09	4.10 ± 0.02	24.87 ± 0.68
F3	4.41 ± 0.02	33.91 ± 0.32	22.49 ± 0.10	4.64 ± 0.03	34.54 ± 0.40
p	0.015*	0.001**	0.015*	0.015*	0.001**

** One-way ANOVA; *Kruskal-Wallis test.

sential amino acid lysine was 2,023.94 mg/100 g (Table 3).

Threonine, leucine, valine, isoleucine, and serine levels were not significantly different between the fermentation treatments ($p > 0.05$). However, significant differences in the levels of histidine, lysine, phenylalanine, proline, tyrosine, aspartic acid, glycine, alanine, arginine, and glutamic acid were observed between the fermentation treatments ($p < 0.05$). The highest total amino acid content was detected in mackerel sausage fermented for 3 days at 10,940.85 mg/100 g.

Total amino acid content in the fermenting and control sausage was 10,935.52 mg/100 g on day 0. Total amino acid content decreased to 9,656.64 mg/100 g on day 1 of fermentation. Total amino acid content increased from day 1 to 10,364.19 mg/100 g on day 2 of fermentation. The levels of some amino acids and total amino acid content increased on day 3 of fermentation. However, the levels of proline, aspartic acid, glycine, and glutamic acid decreased. The main amino acid in mackerel was glutamic acid (3,583.73 mg/100 g), which agreed with previous studies conducted by Nurjanah et al. (2015) and Oluwaniyi et al. (2010) that mackerel is rich in glutamic acid. The high glutamic acid content in mackerel is caused by deamination of glutamine (Nurjanah et al., 2015).

Total amino acid content in the fermented sausages increased to 10,940.85 mg/100 g on day 3, which was higher than the total amino acid content in mackerel, the control sausage, or the fermented sausage on days 1 and 2. Changes in the amino acid levels in fermented mackerel sausage differed among the amino acid groups (Table 4).

Total amino acid content decreased on day 1 of fermentation compared to the unfermented mackerel sausage because of the high level of amino acid anabolism needed for LAB to adapt and grow (Nursyam, 2011; Sulaiman et al., 2016). Marathe and Ghosh (2009) showed that LAB require peptides, vitamins, and protein catabolic compounds, such as nitrogen and amino acids, to grow. Total amino acid content increased on days 2 and 3 of fermentation. The increase in total amino acid content during fermentation was caused by LAB hydrolysing the protein components into amino acids (Nursyam, 2011).

The WHO suggests daily lysine intake of 45 mg/g protein (World Health Organization et al., 2007) or 30 mg/kg body weight (World Health Organization et al., 2007) (Table 1). According to the Nutritional Adequacy Rate 2019 (Republic of Indonesia, 2019), adult males must consume 65 g protein/day and adult females must consume 60 g/day. An average 100 g fermented mackerel sausage contained 1.066,58 mg lysine, which equalled 36% of the recommended daily nutrient intake of lysine for an adult male and 40% for an adult female.

3.3 Fatty Acid Composition

The major fatty acids detected in mackerel were UFA, including PUFAs of 60 mg/100 g, MUFAs of 25 mg/100 g, SFAs of 60 mg/100 mg, and omega-3 fatty acids of 42.25 mg/100 g (Table 5). Unsaturated fatty acids, PUFAs, and MUFAs did not differ after fermentation ($p > 0.05$), whereas

Table 3: Amino acid composition of mackerel (mg/100 g)

Amino Acid (AA)	Amino Acid Levels
Essential Amino Acids	
Histidine	1,094.68 ± 1.38
Threonine	1,149.92 ± 0.69
Leucine	1,731.73 ± 2.62
Lysine	2,023.94 ± 2.97
Valine	1,147.63 ± 0.11
Isoleucine	1,040.33 ± 0.82
Phenylalanine	970.86 ± 1.25
Arginine	1,355.77 ± 1.39
Total of Essential Amino Acids	10,514.86
Non-Essential Amino Acids	
Proline	633.81 ± 0.34
Tyrosine	760.84 ± 43.92
Aspartic Acid	2,311.91 ± 5.32
Glycine	931.22 ± 1.51
Alanine	1,238.97 ± 2.45
Glutamic Acid	3,583.73 ± 5.40
Serine	902.36 ± 2.33
Total of Non-Essential Amino Acids	10,362.84
Total of AA	20,877.70

SFAs and omega-3 fatty acid levels were significantly different after fermentation ($p < 0.05$). The third day of fermentation recorded the highest total fatty acid content of 11,428.73 mg/100 g. Total fatty acid content was 11,130.60 mg/100 g on day 0 of fermentation (control). The PUFA and MUFA levels in the control sausage were higher than the SFA levels. Total fatty acid content decreased to 6.921,9 mg/100 g on day 1 of fermentation, whereas fatty acid levels increased on days 2 and 3 of fermentation (Table 6).

The results of this study showed that mackerel flesh contained high unsaturated fatty acid contents, namely PUFAs of 60 mg/100 g and MUFAs of 25 mg/100 g. Mackerel flesh also contained SFAs of 60 mg/100 mg and omega-3 fatty acids of 42.25 mg/100 g. This composition differed from those reported by Marichamy et al. (2009), Nurjanah et al. (2015), and Sonavane et al. (2017) because the species, season, environment, and quality of feed influence the composition of fatty acids in mackerel (Özogul & Özogul, 2007; Sonavane et al., 2017).

Adding corn oil as a substitute for animal fat during fermentation increased the levels of SFAs, MUFAs, and PUFAs in the fermented sausage, compared to raw mackerel flesh because corn oil naturally contains PUFAs (54.7% of total fatty acids), MUFAs (27.6% of total fatty acids), and SFAs (13% of total fatty acids) (St-Onge & Travers, 2016). The levels of SFAs, PUFAs, MUFAs, and omega-3 fatty acids decreased on day 1 of fermentation because the oxidation process was faster due to high unsaturation. The oxidation rate is determined by the quality of the flesh, temperature, exogenous components (seasoning, nitrate, and salt), and the antioxidant protective effect of the food ingredients (Nassu et al., 2003; Talon et al., 2000; Visessanguan et al., 2006). Total fatty acids increased gradually on days 2 and 3 of fermentation. The increase in fatty acids indicates lipolysis by LAB (Visessanguan et al., 2006), as LAB secrete lipolytic enzymes to breakdown fat into free fatty acids

Table 4: Amino acid composition of mackerel (mg/100 g)

Amino Acids (AA)	Duration of Mackerel Sausage Fermentation					p-Value
	Fresh mackerel (48%)[c]	Day 0	Day 1	Day 2	Day 3	
Essential Amino Acids						
Histidine	52.,44 ± 0.66*	611.82 ± 3.44*	289.79 ± 0.49*	331.05 ± 0.07*	491.60 ± 5.47*	$p < 0.001^a$
Threonine	551.96 ± 0.33	662.22 ± 1.61	541.71 ± 1.96	555.83 ± 2.15	651.01 ± 6.09	$p = 0.068^b$
Leucine	831.23 ± 1.26	885.17 ± 10.13	856.32 ± 2.04	865.86 ± 1.71	966.45 ± 8.50	$p = 0.068^b$
Lysine	971.49 ± 1.43*	1,112.45 ± 5.61*	1,038.63 ± 5.41*	1,093.18 ± 3.95*	1,067.94 ± 7.38	$p < 0.001^a$
Valine	550.86 ± 0.57	617.94 ± 1.90	551.75 ± 1.41	575.68 ± 1.29	671.10 ± 4.46	$p = 0.081^b$
Isoleucine	499.36 ± 0.40	517.64 ± 12.38	508.93 ± 0.80	517.57 ± 0.24	598.37 ± 8.05	$p = 0.101^b$
Phenylalanine	466.01 ± 0.60*	510.66 ± 13.71	410.96 ± 0.68*	416.47 ± 0.74*	530.09 ± 6.30*	$p < 0.001^a$
Arginine	650.77 ± 0.66*	557.08 ± 5.22*	554.14 ± 2.36*	603.68 ± 0.78*	676.60 ± 6.38*	$p < 0.001^a$
Total Essential AA	5,047.13	5,474.98	4,752.23	4,962.32	5,653.16	
Non-Essential Amino Acids						
Proline	304.23 ± 0.16*	356.50 ± 3.20*	329.52 ± 0.74*	422.45 ± 0.09*	385.68 ± 5.40	$p < 0.001^a$
Tyrosine	365.20 ± 21.08	310.06 ± 0.69*	272.56 ± 0.60*	268.15 ± 0.30*	341.72 ± 3.28*	$p = 0.001^a$
Aspartic Acid	1,109.71 ± 2.56*	1,175.20 ± 1.42*	1,061.64 ± 2.98*	1,122.92 ± 1.32*	1,082.61 ± 9.98	$p < 0.001^a$
Glycine	446.98 ± 0.73*	524.43 ± 0.98*	440.00 ± 1.73*	603.00 ± 1.68*	550.13 ± 5.35*	$p < 0.001^a$
Alanine	594.70 ± 1.18*	722.24 ± 3.10*	644.61 ± 2.73*	732.06 ± 2.50*	700.94 ± 5.90*	$p < 0.001^a$
Glutamic Acid	1,720.19 ± 2.60*	1,834.40 ± 5.30*	1,709.17 ± 8.41*	1,794.31 ± 5.96*	1,681.46 ± 11.16*	$p < 0.001^a$
Serine	433.13 ± 1.12	537.71 ± 8.99	446.91 ± 1.11	461.98 ± 0.75	545.15 ± 6.70	$p = 0.078^b$
Total Non-Essential AA	4,974.16	5,460.54	4,904.41	5,401.87	5,287.69	
Total AA	10,021.30	10,935.52	9,656.64	1,364.19	10,940.85	

Note: * significant difference in mean value. a = ANOVA; b = Kruskal-Wallis test; c, indicates the amount of mackerel in the fermented sausage.

during fermentation.

The American Heart Association (AHA) recommends consuming 1 g of omega-3 PUFAs/day (Cao et al., 2015). An average 100-g serving of fermented mackerel sausage contained 416.5 mg of omega-3 fatty acids, which is equal to 42% of the omega-3 daily intake recommended by the AHA. Therefore, it is suggested to consume at least two or three fermented mackerel sausages per day to meet the recommendation.

3.4 Physical Characteristics (Hardness and Springiness)

The 3-day fermentation treatment produced the hardest texture of mackerel sausage compared to the other treatments, whereas the 1-day fermentation produced sausage with the best springiness compared to the other treatments. This is consistent with a previous study on fermented catfish sausage, in which the levels of hardness and springiness were not much different (Nisa & Wardani, 2016). Significant differences in the hardness and springiness levels were observed in fermented mackerel sausage compared to the control (Table 7).

3.5 Acidity Level (pH)

The 3-day fermented mackerel sausage had the lowest pH compared to the other treatments. In this study, fermented mackerel sausage experienced a mild decrease in pH. This result agreed with a study on fermented catfish sausage (Nisa & Wardani, 2016), in which a relatively small pH decrease was reported. Significant differences in pH were observed on the different days of fermentation (Table 8).

3.6 Organoleptic Test (Acceptability)

A hedonic test was used to rate how panellists assessed mackerel sausage after the different fermentation times. The panellists were asked to evaluate the colour, aroma, taste, and texture

Table 5: Fatty acid composition of mackerel (mg /100 g)

Fatty Acids	Level of Fatty Acids
Saturated fatty acid (SFA)	60.00 ± 0.00
Monounsaturated fatty acid (MUFA)	25.00 ± 7.07
Polyunsaturated fatty acid (PUFA)	60.00 ± 0.00
Unsaturated fatty acid	80.00 ± 0.00
Omega-3 fatty acid	42.25 ± 1.06
Total Fatty Acids	187.25

Table 6: Fatty acid composition in mackerel (48%) and fermented sausage (mg/100 g)

Fatty Acids	1	Duration of Mackerel Sausage Fermentation				*P-Value*
	Fresh mackerel (48%)[c]	Day 0	Day 1	Day 2	Day 3	
Saturated fatty acid (SFA)	28.80 ± 0.00*	2,255.00 ± 7.07*	1,130.00 ± 14.14*	1,445.00 ± 21.21*	2,335.00 ± 7.07*	$p < 0.001^a$
Monounsaturated fatty acid (MUFA)	12.00 ± 3.39	3,030.00 ± 0.00	2,020.00 ± 14.14	2,110.00 ± 0.00	3,175.00 ± 7.07	$p = 0.065^b$
Polyunsaturated fatty acid (PUFA)	28.8 ± 0.00	5,210.00 ± 14.14	3,535.00 ± 21.21	3,695.00 ± 7.07	5,300.00 ± 14.14	$p = 0.067^b$
Unsaturated fatty acid	38.40 ± 0.00	8,250.00 ± 14.14	5,555.00 ± 35.36	5,805.00 ± 7.07	8,480.00 ± 28.28	$p = 0.067^b$
Omega 3 fatty	20.28 ± 0.51*	625.60 ± 3.54*	236.90 ± 1.56*	398.85 ± 7.00*	613.73 ± 0.46*	$p < 0.001^a$
Total	89.88	11,130.60	6,921.90	7,648.85	11,428.73	

Note: * indicates a significant difference in mean value. [a] ANOVA. [b] = Kruskal-Wallis test. [c] indicates the amount of mackerel in a fermented sausage.

Table 7: Average physical characteristics (hardness and springiness) of fermented mackerel sausage

Formula	(Mean ± Standard Deviation)	
	Hardness	Springiness
F0	762.16 ± 93.65	7.3 ± 2.51
F1	708.33 ± 86.61	9.5 ± 0.36
F2	3,030.00 ± 316.82	9.4 ± 0.11
F3	4,781.33 ± 332.88	9.2 ± 0.05
P	<0.001**	0.047*

** One-way ANOVA; * Kruskal-Wallis test.

Table 8: Average pH level of fermented mackerel sausage

Formula	pH (Mean ± Standard Deviation)
F0	5.69 ± 0.02
F1	5.62 ± 0.01
F2	5.59 ± 0.02
F3	5.46 ± 0.04
P	<0.001**

** One-way ANOVA; * Kruskal-Wallis test.

of the sausage. Significant differences in the acceptability of colour, aroma, taste, and texture of mackerel fermented sausage were observed depending on the day of fermentation. The most preferred type was F0 (day 0), while the second most favourable was F1 (day 1). This result is similar to fermented catfish sausage, of which the day 0 and day 1 fermentation types are favoured (Table 9).

The colour parameter is the first consideration when consumers choose a food product. If the colour of the food is not attractive, it will reduce consumer acceptance even though nutritional content is complete. There was a marked difference in colour acceptability between F0 and F1. The colour of the control sausage (F0) tended to

Table 9: Acceptability of fermented mackerel sausage

Formula	(Mean ± Standard Deviation)			
	Colour	Aroma	Taste	Texture
F0	3.80 ± 0.55 (Really like)	3.77 ± 0.72 (Really like)	3.70 ± 0.70 (Really like)	3.63 ± 0.76 (Really like)
F1	3.23 ± 0.56 (Like)	3.20 ± 0.61 (Like)	3.30 ± 0.59 (Like)	3.37 ± 0.55 (Like)
F2	2.10 ± 0.48 (Dislike)	2.20 ± 0.76 (Dislike)	2.53 ± 0.62 (Dislike)	2.17 ± 0.79 (Dislike)
F3	2.03 ± 0.80 (Dislike)	2.03 ± 0.85 (Dislike)	2.07 ± 0.94 (Dislike)	1.67 ± 0.54 (Really dislike)
P	<0.001*	<0.001*	<0.001*	<0.001*

** One-way ANOVA; * Kruskal-Wallis test.

Table 10: Deviation values of nutritional quality, physical texture, pH, and acceptability formulation of fermented mackerel sausage

Variable	NP				Nba	Nbu	S
	F0	F1	F2	F3			
Carbohydrate	13.91	19.18	24.87	34.54	13.91	34.54	-20.63
Protein	15.34	20.62	31.97	33.91	33.91	15.34	18.57
Fat	3.37	3.55	4.20	4.41	3.37	4.41	-1.04
Water	65.32	53.79	34.83	22.49	22.49	65.32	-42.83
Ash	2.05	2.84	4.10	4.64	2.05	4.64	-2.59
Accepted Formulation	14.9	13.1	9.0	7.8	14.9	7.8	7.1
Elasticity	7.3	9.5	9.4	9.2	9.5	7.3	2.2
Hardness	762.16	708.33	3,030.00	4,781.33	708.33	4,781.33	-4,073
pH	5.69	5.62	5.59	5.46	5.46	5.69	-0.23

Note: treatment value (NP), the best treatment value (Nba), the worst treatment value (Nbu), Δ Nba and Nbu (S).

be clean brownish-white and lighter, while the F1 colour was brownish-white and slightly darker. The colour became darker during fermentation due to the Maillard reaction. The Maillard reaction occurs when the carbonyl compounds from the smoking process react with amino acids in the food. The colour formed on smoked food products is related to temperature, humidity, and protein content. Generally, the longer the fermentation, the darker the colour, so that fermentation further reduces the colour acceptability of fermented mackerel sausage (Rozum, 2009).

Aroma is important because it determines the quality of a food product. Aroma arises from volatile substances that are soluble in water and fat (Zhang et al., 2010). The longer the fermentation, the lower the aroma acceptance of fermented mackerel sausage. The acceptance test results indicated this for the F0 and F1 fermented mackerel sausage. The least preferred were the F2 (day 2) and F3 (day 3) fermented sausages.

Taste is an organoleptic property that greatly affects preference for a product and determines the decision to reject or accept the final product. The most preferred and preferred fermented mackerel sausages were the F0 and F1, sausages,

Table 11: Weights and scores for the best fermented mackerel sausage formula

Variable	BV	BN	F0		F1		F2		F3	
			Ne	Nh	Ne	Nh	Ne	Nh	Ne	Nh
Carbohydrate	0.8	0.10	1	0.1	0.71	0.071	0.46	0.046	0	0
Protein	1	0.13	0	0	0.28	0.036	0.89	0.115	1	0.13
Fat	1	0.13	1	0.13	0.82	0.106	0.20	0.026	0	0
Water	0.5	0.06	0	0	0.26	0.015	0.71	0.042	1	0.06
Ash	0.5	0.06	1	0.06	0.69	0.041	0.20	0.012	0	0
Accepted Formulation	1	0.13	1	0.13	0.74	0.096	0.16	0.020	0	0
Elasticity	0.8	0.10	0	0	1	0.10	0.95	0.095	0.86	0.086
Hardness	0.8	0.10	0.98	0.098	1	0.10	0.42	0.042	0	0
pH	1	0.13	0	0	0.30	0.039	0.43	0.055	1	0.13
Total	7.4	0.94	4.98	0.518	5.8	0.604	4.42	0.453	3.86	0.406

Note: variable weight (BV), normal weight (BN), effectiveness value (Ne), and yield value (Nh).

respectively. The longer the fermentation, the sourer the sausage will taste. The sour taste occurs because lactic acid is derived from low molecular weight compounds, such as peptides and free amino acids, aldehydes, organic acids, and amines produced by proteolysis (Zhang et al., 2010). The fermented mackerel sausage produced lactic acid and produced a small amount of acetic acid, ethanol, acetoin, carbon dioxide, and pyruvic acid, which imparted a sour taste to the sausage (Lazic et al., 2019; Zhang et al., 2010).

The texture of sausage is chewy. In this study, the most preferred textures of the fermented mackerel sausage were the F0 and F1. The components of fermented mackerel sausage that contributed to the texture were tapioca flour, carrageenan, and skim milk. The difference in the degree of chewiness is due to the amount of myofibril proteins (actin and myosin) that determine the gel properties of the sausage. Adding carrageenan helps in the formation of the elastic gel, which increases elasticity (Goff & Guo, 2019). Furthermore, the interaction between proteins and polysaccharides in foodstuffs plays an important role in the structure and stability of processed products (Ayadi et al., 2009).

3.7 Selected Formula Weight

Results of the analysis based on the de Garmo method showed that the 1-day fermented mackerel sausage (F1) had the best formula (Table 10 and Table 11). It scored the highest yield value (Nh) of 0.604 with 19.18% carbohydrate, 20.62% protein, 3.55 % fat, 53.79% water, 2.84% ash, 9.5 mm thickness, 708.33 g hardness, 5.62 pH, 3.23 colour, 3.20 aroma, 3.30 taste, and 3.37 texture. The best formulation was determined based on the de Garmo analysis. The assessment of the fermented mackerel sausage considered all variables that played a role in determining product quality, including nutritional quality, physical properties, pH, and organoleptic properties. The variables of nutrition (fat, protein), pH, and organoleptic quality were given the same weight because they were considered equally important in determining consumer interest in a new food product. The pH value indicates whether LAB are growing in the fermented product (Lazic et al., 2019; Nisa & Wardani, 2016). Fermented mackerel sausage with a fermentation time of 1 day was chosen as the best formulation.

4 Conclusions

A longer fermentation time resulted in higher nutritional quality (protein, fat, carbohydrates, and ash), and the hardness level increased. However, the acceptance variable (colour, aroma, taste, and texture), pH, and the degree of elasticity decreased as fermentation progressed. Different results for each type of amino acid and fatty acid were detected for the different fermentation

durations. Overall, fermentation played a role increasing amino acid and fatty acid composition. The best formulation for fermented mackerel sausage was a fermentation time of 1 day. It scored the highest yield value (Nh) of 0.604 with 19.18% carbohydrate, 20.62% protein, 3.55 % fat, 53.79% water, 2.84% ash, 9.5 mm thickness, 708.33 g hardness, 5.62 pH, 3.23 colour, 3.20 aroma, 3.30 taste, and 3.37 texture.

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Sourdoughs Used in the Preparation of Traditional Bread in the Province of Figuig in Eastern Morocco

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Abstract

To gather recipes for traditional sourdoughs used to bake traditional bread, a survey was conducted in Figuig, a town located in the southeast of Morocco. The data of this survey is collected from a random sample of 100 rural women using a structured questionnaire. The data shows a total of 17 different traditional recipes mentioned by the interviewed women. Among the ingredients used in these recipes, whole wheat flour and warm water had the highest percentage of citations (31 %). It was also observed that 9 local products were used in these sourdough recipes, including whey, locally called "leben" (19 %), dried beans (16 %) and dates (15 %). Lemon, garlic, dried figs, raisins, flax seeds and carob flour were also mentioned as ingredients (1%). The participants also stated that the sourdoughs are transferred to different shapes and types of utensils for incubation and were alive for a variable amount of time depending on climatic conditions.

Keywords: Food survey; Sourdough; Traditional recipe; Figuig

1 Introduction

Sourdough bread is a traditional food product, fermented with sourdough, and has been known since ancient times (Lau et al., 2021; Marsh et al., 2014). The preparation begins with a sourdough starter, a natural leaven composed of wheat or barley flour and water. This mixture forms a sponge-like product which is then kept at room temperature and refreshed on a daily basis, for several days, to develop into a sourdough chief (Figure 1). The fermentative activity of sourdough, during baking, is the result of the mixture of microflora in the sourdough, composed of "wild" yeasts and lactic acid bacteria (LAB) (Table 1).

Wild yeasts *(Saccharomyces cerevisiae, Saccharomyces exiguus, Candida krusei, Candida guillermondii, Candida holmii, Torulopsis holmii, Hansenula anomala and torulaspora delbrueckii)* are responsible for the production of CO_2, lactic acid and lactic bacteria (LAB). The later are subdivided into heterofermentative and homofermentative lactic acid bacteria *(Fructilactobacillus sanfranciscensis, Limosilactobacillus fermentum, Lactiplantibacillus plantarum, Leuconostoc mesenteroides, Levilactobacillus brevis subsp. lindneri, Lactobacillus fructivorans, Lactobacillus alimentarius)* (Table

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1).
Heterofermentative LAB produce a mixture of lactic acid and acetic acid while homofermentative LAB only produce lactic acid which acidifies the sourdough growth environment very quickly (Galimberti et al., 2021). The synergistic interaction between the wild yeasts and the LAB, during the fermentation phase, allows production of special and unique aromatic precursors, increases volume of the bread and decreases firmness of the bread. It also functions as a probiotic reducing the pH, which helps the optimization of the sourdough bread's shelf life (Carbonetto et al., 2020; Galle et al., 2010; Gobbetti et al., 2014; Hui et al., 2004; Kaditzky et al., 2008; Katina et al., 2009; Lau et al., 2021; Rühmkorf et al., 2012; Tieking & Gänzle, 2005; Zhang et al., 2021).
The purpose of this work was to establish an inventory of sourdough recipes used in the traditional process of sourdough bread making, by women from the town of Figuig. The data will serve as a source of information on the varieties and methods of sourdough starters (Mannaa et al., 2021). It also aims to provide research data in the area of food safety and research into natural probiotics as a way to treat certain metabolic diseases including diabetes, celiac disease and non-alcoholic fatty liver disease which are global health issues (Pasqualone, 2018; Stefan & Häring, 2013).

Figure 1: Sourdough starter. Sourdough starter prepared with a mixture of whole wheat flour (15 %), whole barley flour (15 %) and lukewarm water (70 %). CO_2 production is shown by a smaller size of bubbles. (Taken on 18 March 2020 at Figuig. Picture provided courtesy of the author MOUJABBIR Sara)

2 Materials and Methods

2.1 Study area

The survey took place in the town of Figuig (Figure 2) called in the local language Amazigh language: Ifyyey or Figuig. The province is located in the extreme southeast of Morocco (latitude 32^o 7 '0 "N, longitude 1^o 13 '37 "W). It is bordered by the province of Jerada to the north, the province of Boulemane to the northwest, the province of Errachidia to the west and by the Moroccan-Algerian border to the south and east. Figuig province includes seven different communes (Ighermawen in Tamazight, Arabic: قصر, namely, At-wattay (Hamam tahtani), At-Amar (Hamam Foukani), At-lamiz (El Maiz), At-Sliman (Oulad Slimane), At-Annaj (Laâbidate), At-Addi (Loudaghir) and Iznayen (Zenaga) (Monographie de la province de Figuig, 2013). Figuig is an oasis famous for its different varieties of dates (tiyni), which include "Assign", "Aziza", "Boufeggous", "Mejhoul" and "Tgharas" (Chafi et al., 2015; Yauo, 2012). The province is also known for some famous traditional dishes like "Mihmih", "Zembou", "Ourif", "Klila" (type of cheese) and "Aghroum n'tamtunt" (local bread).

2.2 Samples

The women surveyed belong to 7 localities selected as shown in Figure 3. These localities are called "ksar" in the local language (plural "ksour") and are Zenaga "Iznayen": Baghdad, tachraft; Loudaghir "At Addi"; Laâbidate "At ennej"; Oulad Slimane "At Slimane": Dfilia, aarga; Hamam Tahtani "At Wattay"; Hamam Foukani "At Amer" and El Maïz "At Lemaïz". The study participants are rural women randomly selected and their number varies according to each locality in the study area (Table 2; Figure 3).
Inclusion criteria are the rural location of the respondents place of residence and the use of

Table 1: Example of microflora: LAB and yeast most isolated in sourdough (Gobbetti et al., 2014)

Lactic acid bacteria and wild yeast		
Lactic acid bacteria	**Yeasts**	**References**
Lactobacillus delbrueckii, Lactobacillus plantarum, Lactobacillus fermentum, Lactobacillus buchneri, Lactobacillus brevis, Levilactobacillus brevis subsp. lindneri, Lactobacillus fructivorans, Lactobacillus alimentarius	*Saccharomyces cerevisiae, Candida krusei, Candida holmii*	Corsetti and Settanni (2007), Katsi et al. (2021), Zameitat et al. (2007), and Zhang et al. (2021)
Fructilactobacillus sanfranciscensis, Lactobacillus plantarum, Lactobacillus fermentum, Leuconostoc mesenteroides, Pediococcus spp,	*Saccharomyces cerevisiae, Candida stellata, Torulopsis holmii*	García et al. (2018), Zameitat et al. (2007), and Zhang et al. (2021)
Levilactobacillus brevis subsp lindneri, Lactobacillus plantarum, Lactobacillus fermentum, Lactobacillus pontis.	*Candida guillermondii, Candida holmii, Saccharomyces cerevisiae, Hansenula anomala, torulaspora delbrueckii, Saccharomyce exiguus, Candida krusei*	Hellborg and Piškur (2009) and Katsi et al. (2021)

Figure 2: Locality of the study area "Figuig". (Image from Google Earth, modified by the author)

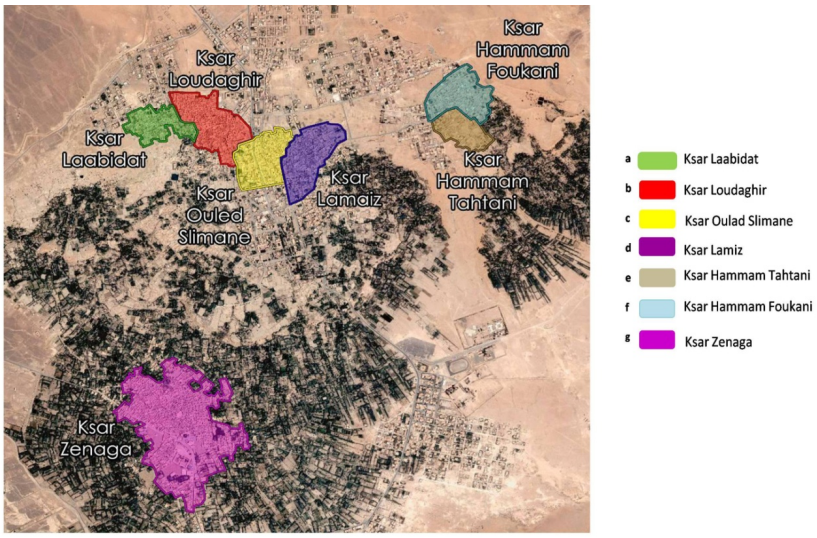

Figure 3: Monograph of seven Ksour in the study area: (a) ksar laabidat, (b) ksar Loudaghir, (c) ksar oulad sliman , (d) ksar Lamiz, (e) ksar hammam tahtani, (f) ksar hammam foukani, (g) ksar Zenaga. (Image from Monographie de la province de Figuig (2013), modified by the author)

Table 2: Distribution of the study sample of women bakers according to age.

	Age range (%)	
Ksar	40-50 yrs	60-80 yrs
Zenaga "Iznayen": Baghdad, tachraft	10	19
Loudaghir "At Addi	-	11
Laâbidate "At ennej "	-	10
Oulad Slimane "At Slimane": Dfilia, aarga	6	12
Hamam Tahtani "At wattay"	-	11
Hamam Foukani "At Amer"	-	10
El Maïz "At Lemaïz"	2	9

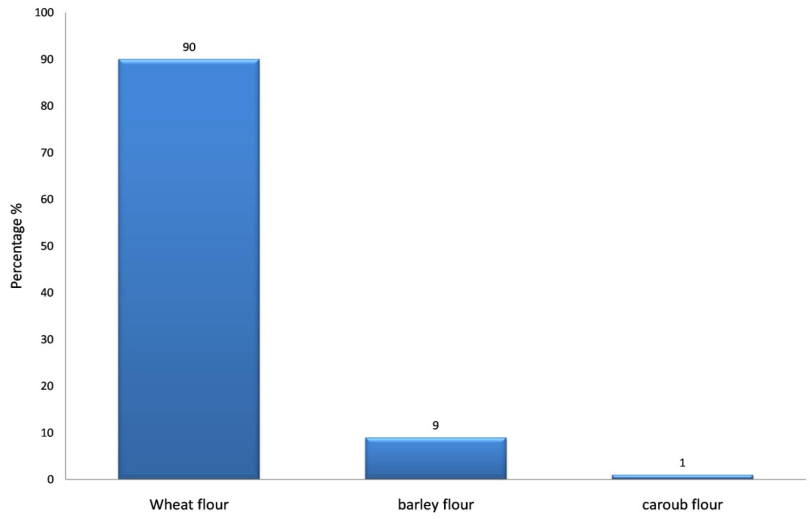

Figure 4: Basic ingredients used to make the initial sourdough starter

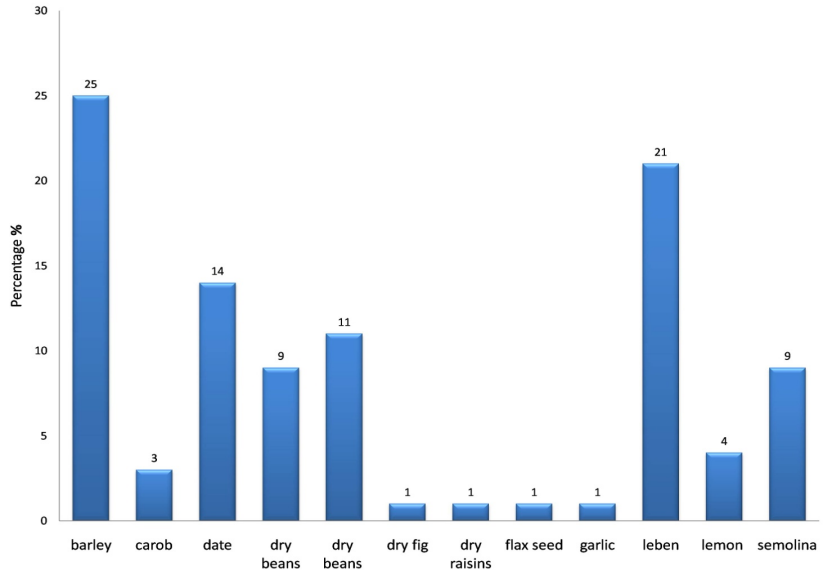

Figure 5: Ingredients used to speed up the fermentation process

Table 3: Description of the sourdough

Recipe		Sourdough type	Usage	Incubation condition	Conservation utensil
125 g wheat + 125 g water + 125 g barley	12%	Stiff or dry or liquid	- Bread - Moroccan soup or 'Harira'	- Stiff and liquid: ambient temperature - Dry: solar exposure	- Stiff: flour - Liquid: glass jars - Dry: raffia dish
125 g wheat + 250 g water + 2 dates	9%	Liquid	Bread	Ambient temperature	Goat skin
125 g wheat + 125 g water + 125 g 'lben' + 1 spt lemon juice	1%	Liquid	Bread	Ambient temperature	Glass jars
125 g wheat + 125 g water	32%	Stiff or dry or liquid	- Bread - "Harira" soup	- Stiff and liquid: ambient temperature - Dry: solar exposure	- Stiff: flour - Liquid: glass jars - Dry: raffia dish
125 g wheat +125 g water +125 g "lben"	12%	Liquid	Bread	Solar exposure	Clay jars
125 g wheat + 500 g water + 100 g barley + 100 g carob + 1 spt flax seed + 1 date	1%	Liquid	Bread	Ambient temperature	Glass jars
250 g wheat + 125 g water + 125 g barley + 2 date	3%	Stiff	Bread	Ambient temperature	Flour
250 g wheat + 125 g water + 1 garlic	1%	Stiff	Bread	Ambient temperature	Glass jars
125 g wheat + 2 dry beans + 250 g "lben"	3%	Liquid	Bread	Ambient temperature	Glass jars
250 g barley + 2 dry beans + 125 g water	6%	Stiff	Bread	Ambient temperature	Glass jars
125 g wheat + 125 g water + 1 spt yeas t+ 2 date + 125 g "lben"	1%	Liquid	Bread	Ambient temperature	Glass jars
125 g wheat + 125 g water + 2 dry beans + 125 g "lben"	5%	Liquid	Bread	Ambient temperature	Glass jars
125 g wheat + 125 g water + 125 g barley + 125 g semolina	1%	Stiff	Bread	Ambient temperature	Glass jars
125 g wheat + 2 date+ 250 g "lben"	2%	Liquid	Bread	Ambient temperature	Clay jars
125 g wheat + 125 g water + 125 g semolina	8%	Stiff	Bread	Ambient temperature	Glass jars
125 g wheat + 250 g water + 125 g barley + 3 dry fig	1%	Liquid	Bread	Ambient temperature	Glass jars
125 g wheat + 500 g water + 125 g barley + 15 dry grapes	1%	Liquid	Bread	Ambient temperature	Glass jars

traditional sourdough in bread making. An exclusion criterion is the use of dry yeast in this process. The questionnaire was completed with each woman in the household. Two main languages, Arabic and Tamazight, were used to collect information from the participants.
The questionnaire is designed to obtain information on:

Socio-demographic characteristics: ethnic origin, mother tongue (Arabic or Tamazight), locality of belonging (ksar) and duration of experience;

Traditional recipes of sourdough starter, type of cereal used in the kneading process, sourdough texture, fermentation conditions, fermentation time, storage utensils and storage temperature;

Profile of sourdough dishes provides information on the sensory profile and texture of wheat or barley bread and harira soup (local soup) subsequently by adding an appropriate and special type of sourdough depending on the recipe.

The main criterion used to categorize sourdough recipes as old and inherited traditional recipes is frequency of reference by the participants.

2.3 Statistical analyzes

Experimental data were subjected to analysis of the percentages and frequencies obtained, using simple descriptive statistical methods with Microsoft Office Excel 2007.
Ethical considerations: Participants were informed about the purpose of the study, the respect of data confidentiality, that their participation is voluntary and that they can leave the

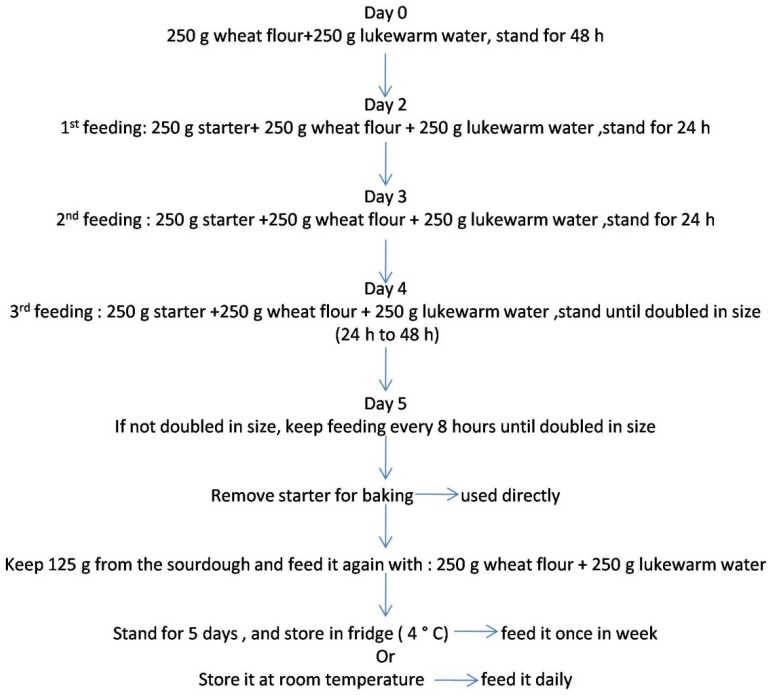

Figure 6: Common procedure adopted by women to make a sourdough chief

survey at any time if they wish. Formal consent was obtained before starting the survey.

3 Results and Discussion

3.1 Sociodemographic characteristics of the participants

The study focused on a total of 100 rural women aged 40 to 80 years old, corresponding to the age group characteristic of the study population that has enough knowledge and significant information on sourdough (Table 2).
As shown in Table 2, the majority of respondents were in the age group of 60 to 80 years representing 82 % of the study population, while 18 % had an average age of 45 years. The high percentage of older women testifies to the know-how inherited from old recipes of sourdough. Moreover, the diversity of these traditional recipes is part of a specific culinary custom and belongs to each ksar (locality) of the study area.

3.2 Origin of knowledge

The majority of the respondents (90 %) declared having acquired almost all of their information and methods of making sourdough by inheritance from their ancestors. Consequently, all the know-how is exclusively transmitted by the oldest members of the community (over 60), which proves that traditional food knowledge is monopolized by the elderly members of families.

3.3 Chronology of sourdough production

Main ingredients for the preparation of sourdough starter

The most popular recipes described by the rural women for the preparation of the sourdough

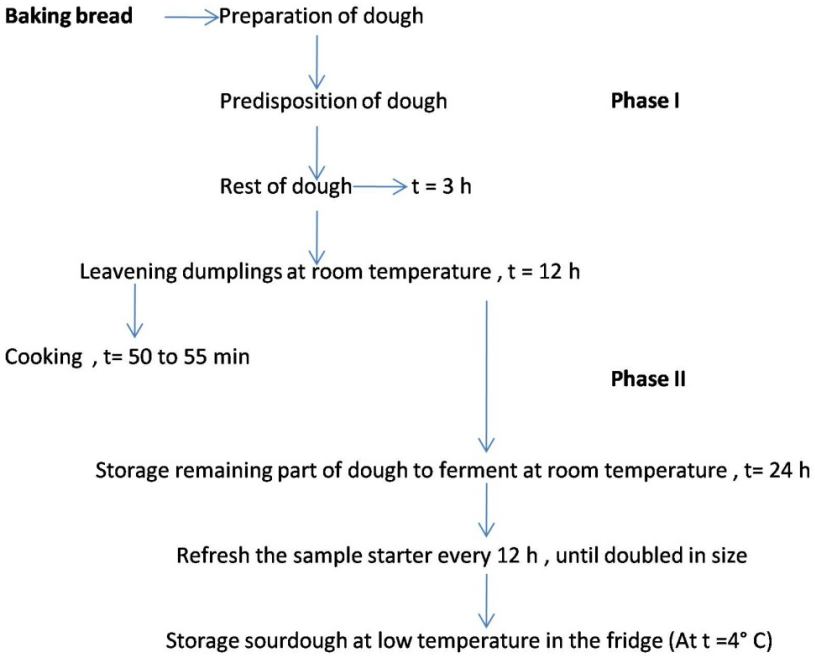

Figure 7: Baking protocol 1, adopted to create a sourdough starter

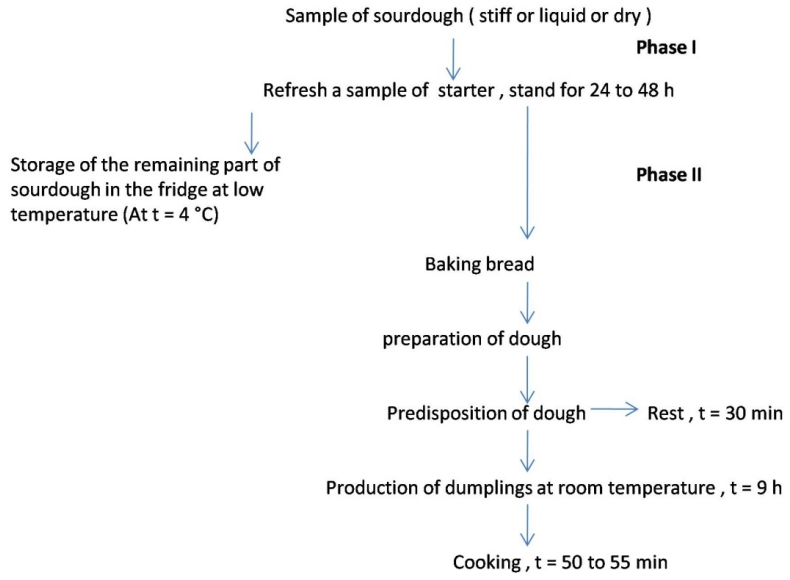

Figure 8: Baking protocol 2, adopted to create a sourdough starter

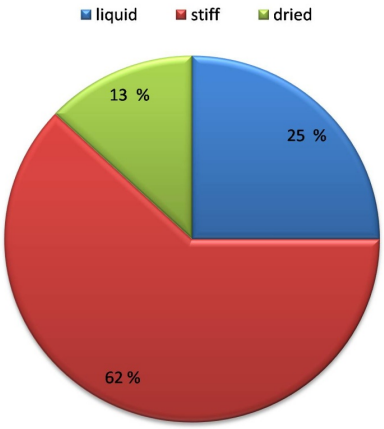

Figure 9: Final texture of sourdough starter

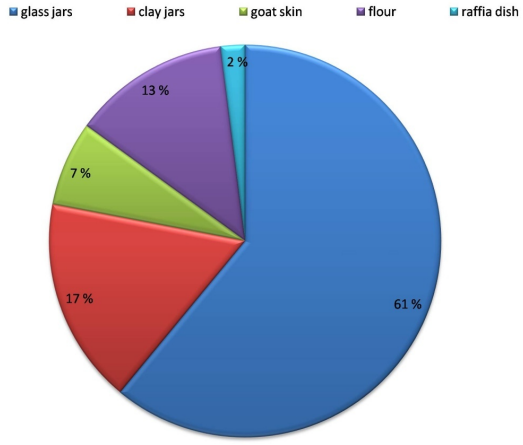

Figure 10: Types of utensil used to preserve different sourdoughs.

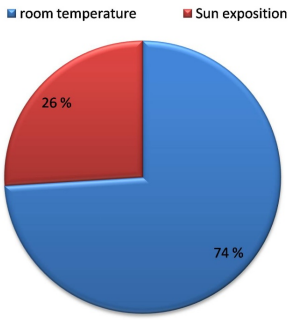

Figure 11: Incubation temperature according to the fermentation method of sourdough

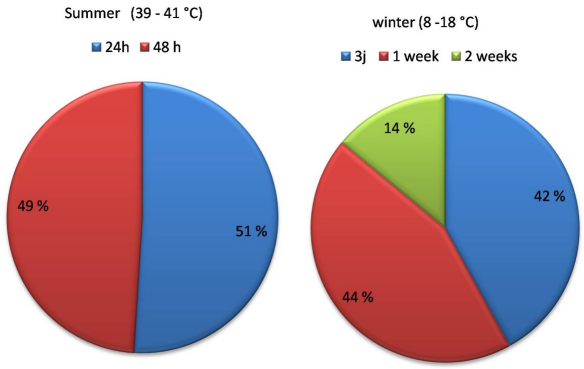

Figure 12: Incubation period according to climate change

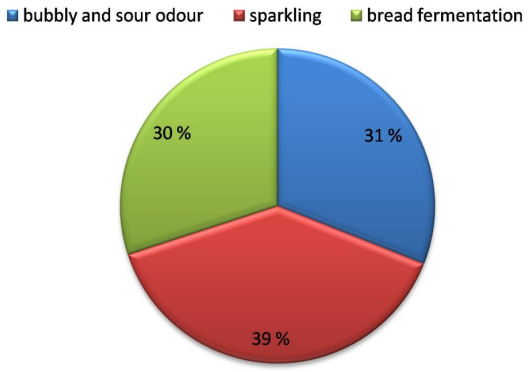

Figure 13: Markers of sourdough liveliness during the fermentation phase

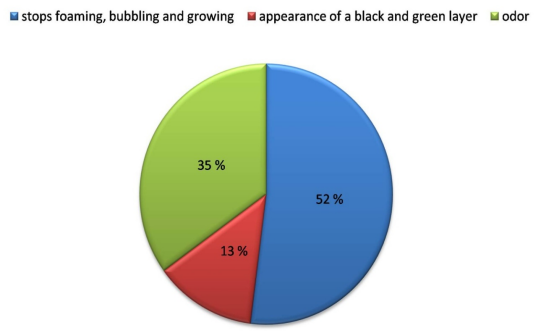

Figure 14: Markers of the death of the sourdough starter

starter are shown in Figures 4 and 5. The collected data comprises 17 different recipes (Table 3), revealing that whole wheat flour "Timzine" (90 %) is mixed with warm water (10 ^{o}C - 15 ^{o}C) in all recipes. However, some women prefer to include other ingredients such as barley flour "Irdan" (25 %), a variety of dates "Tayni" boufeggous (14 %) or whey "Aghi" (21 %) in the wheat/water mixture, to speed up the fermentation process, which varies depending on the season and the climate.

Initial manufacturing process of sourdough starter

After collecting all the recipes from the respondents, a common method of making the sourdough starter and two different protocols of bread baking were revealed. The process of making an initial sourdough starter is relatively long (at least 5 days), depending on the different combination ratios of the yeast and the bacteria existing in the initial whole flour/sourdough starter mixture (Corsetti & Settanni, 2007). To create the initial sourdough starter, the women combine a certain amount of flour with warm water and sometimes a specific local ingredient, to enhance the texture and accelerate the fermentation process.
As shown in Fig. 6 a-c, the current and basic procedure for each woman differs only in the conditions of the fermentation phase (time, temperature and storage condition).

All the prescribed recipes are based on the use of whole wheat or whole barley, or any other type of local ingredients as shown in Table 3.

Sourdough texture

The final texture of the sourdough starter (Figure 9) is determined by the mixture of the ingredients used and the fermentation conditions and time (Figures 10 to 12), and these also determine the viscosity, total acidity and microbiota composition of the final sourdough.
The majority (62 %) of respondents prefer to prepare pasty sourdough, while 25 % favor a liquid texture and 13 % would rather prepare a dry sourdough. Once the process is carried out and the mixture is homogenized, the sourdough is immediately transferred to utensils of different shapes and sizes, mainly in glass jars (61 %) "boukala" but also in clay jars "Taklilte" (17 %) or flour "Aren" (13 %). Then, the preparation is incubated at room temperature (74 %) or sometimes exposed to the sun (26 %) for a period varying between 24 hours (44 %) and a week (42 %). This period can sometimes be longer depending on the season and climate (14 %).

Characteristics of liveliness and stoppage in the fermentation phase of sourdough

Once the sourdough is established, successful fermentation and growth are noticeable in different aspects of sourdough liveliness. According to women, a sourdough is very active and ready to be used as soon as it becomes very foamy or very sparkling (39 %), or if it starts to smell sour (31 %) or when it has an active aspect during bread fermentation (30 %) (Figure 13).
However, 52 % of the women reported that their sourdough does not progress at all (stops foaming, bubbling and rising), while 35 % noted the release of an unusual and unbearable smell. 13 % said that their sourdough forms a green or black layer on the surface because of contamination by harmful bacteria. The appearance of one or the combination of all these markers at the same time indicates the death of the sourdough starter (Figure 14).

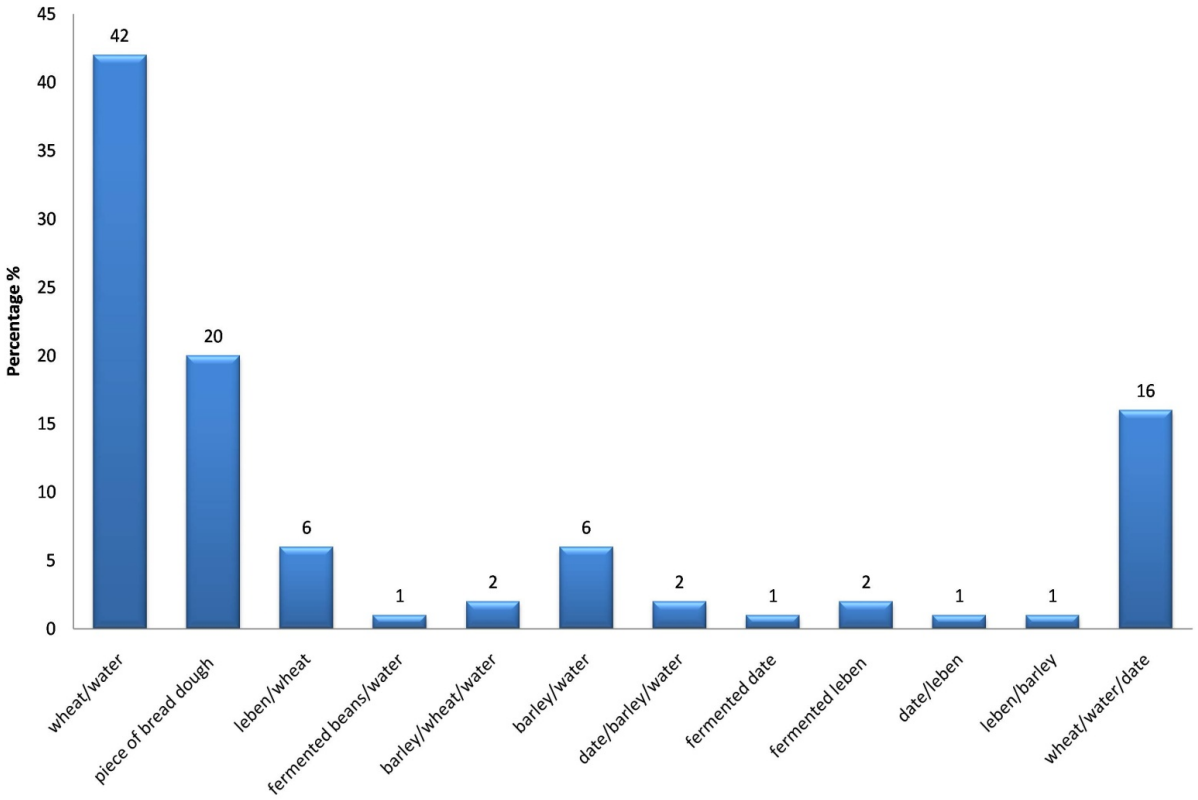

Figure 15: Ingredients used daily or weekly to feed a sourdough chief

Main sourdough "Tamtount"

The term "Tamtount" is used to refer to the final sourdough in the Amazigh language. Once the sourdough is ready, it takes the nomination "main sourdough" (sourdough chief), which must always be fed and refreshed before each kneading to control its sour aspect. 42 % of the study women prefer to refresh their sourdough by adding the same quantities of warm water and flour, depending on how much bread they want to make. However, some women preferred to boost their sourdough with added dough (20 %) or a mixture of wheat, dates and water (16 %). Others preferred to use fermented leben and wheat (6 %) or a mixture of barley and water (6 %) which slightly activates the drowsy sourdough (Figure 15).
At the end of the sourdough-making process, the final volume doubles and the sourdough chief has a very acidic taste, low pH level and a light to dark brown color. Some of these sourdoughs will go through a drying phase for several days in the open air. The dried sourdough obtained is then ground and stored dry at room temperature, while the liquid and stiff sourdough is most often stored cold.

4 Conclusions

This research describes 17 sourdough recipes collected from seven ksour (localities) in the province of Figuig. The data obtained shows that local ingredients are also integrated into the main recipes of sourdough, to accelerate the fermentation process and create a special flavor according to each respondent's recipe. The generated data has created a database on the diversity of sourdoughs and can help safeguard traditional

knowledge about sourdoughs and the different ingredients used as well as the different stages of sourdough preparation and methods of sourdough refreshing.

The results of this study were obtained from rural kneaders in one of the Amazigh regions of Morocco. The data reveals different sourdough recipes for traditional meal preparations such as the famous Moroccan soup "harira" or the traditional Amazigh bread "aghroum". These data also show that these inherited recipes and methods are exclusively known to the oldest members of the family and passed on to younger generations to be saved from extinction.

An analysis of the composition of these sourdoughs according to bacterial microbiota and the determination of their microbiological activity as well as their antioxidant activity would be an important subject of research to further understand the contribution to the improvement of the quality of bread as reported in the literature. The main objectives would be to translate this traditional oral culinary knowledge and heritage into scientific knowledge and, provide invaluable micro and macronutrient compounds of sourdough bread to develop a new food system against health problems such as celiac disease, diabetes and hypercholesterolemia.

Acknowledgements

We especially acknowledge all the women who gratefully participated in this study. The survey was supported by the Moroccan Ministry of Higher Education and Research. This work is also in line with the work from COST Action 18101 SOURDOMICS—Sourdough biotechnology network towards novel, healthier and sustainable food and bioprocesses (https://sourdomics.com/; https://www.cost.eu/actions/CA18101/, where the author J.M.R. is the Chair and Grant Holder Scientific Representative, and the author R.B. is a member as a COST Near Neighbor Country.

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Evaluation of the Formation of Polycyclic Aromatic Hydrocarbons (PAHs) in Chicken Cooked by Saudi Traditional Methods and Their Dietary Risk Assessment

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Abstract

This study evaluates the formation of 13 polycyclic aromatic hydrocarbons (PAHs) in chicken thighs and breasts, cooked by different methods. These methods are: madhbi, charcoal mandi, electric oven mandi, gas flame oven mandi and shawaya. Chicken samples were collected from a restaurant in Riyadh, Saudi Arabia. Analysis of the samples was carried out using high-performance liquid chromatography with a fluorescence detector (HPLC-FLD). The data obtained showed that madhbi chicken had higher PAHs levels than other cooking styles, with the mean concentration in chicken breast of 87.72 μg/kg and thigh of 75.56 μg/kg. Phenanthrene was the compound detected at the highest concentration in different cooking methods. There was no significant difference in concentration of PAHs between the parts of chicken cooked with the same method. However, the method of cooking had a significant impact on the formation of PHAs. Therefore, the formation of PAHs in chicken meat could be reduced by choosing appropriate cooking methods. Moreover, the margin of exposure was used to assess the health risk in adults due to madhbi chicken ingestion. The results showed that there is no serious health concern.

Keywords: PAHs; HPLC; Chicken; Risk Assessment; Margin of Exposure

1 Introduction

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds comprised of carbon and hydrogen, forming two or more aromatic joint rings (Codex Alimentarius Commission, 2009). The formation of PAHs occurs naturally or anthropogenically from the combustion of natural matter, therefore, they are widely dispersed throughout the globe. Industrial activities, wildfires and volcanic eruptions are among the most common PAH sources in the environment (Hokkanen et al., 2018). There are more than 100 different PAHs and, because of their chemical structures, these chemicals tend to become highly lipophilic and stable in the environment (Falcó et al., 2003; Tang et al., 2005).
Human exposure to PAHs occurs through inhalation, dermal contact or the consumption of contaminated foods, which accounts for 88–98% of exposure (Farhadian et al., 2011). Manufacturing processes or cooking methods are responsible for the presence of PAHs in food (Rose et al., 2015), which accumulates by direct

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deposition from the smoke produced by thermal treatment. The pathways of the formation of PAHs in processed food are not well-known. There are at least three possible ways that might lead to the formation of PAHs in meat. The first pathway is by pyrolysis of organic matters such as carbohydrates, proteins and particularly fats at a temperature above 200 ^{o}C. The second mechanism is by the dripping of fat over the heat source, which generates PAHs deposited on the meat (Alomirah et al., 2011; Lee et al., 2016). The incomplete combustion of charcoal is the third pathway, which can form PAHs that adhere to the surface of the food (Alomirah et al., 2011; Chen & Lin, 1997). It is known that PAHs with two or three rings have greater volatility than other PAHs (Szopińska et al., 2019).

Many factors influence the generation of PAHs in food, such as heat source and distance from it. Onwukeme et al. (2015)and Babić et al. (2017) documented 11 parameters that affected the composition and number of PAHs in smoked fish. These were source of heat, distance from heat source, type of wood, moisture content, oxygen accessibility, the temperature of smoke generation, cooking duration, natural content of PAHs in raw meat, water activity of food, fat content and the design of the food device.

The European Union (EU) and the Environmental Protection Agency (EPA) both included PAHs in their priority pollutant lists due to their carcinogenicity (Farhadian et al., 2011). The carcinogenic capacity of PAHs depends on the number of aromatic rings. According to the International Agency for Research on Cancer (IARC), compounds with four to six combined rings are considered class 1 carcinogens (Hokkanen et al., 2018) (Table 1), while the others are classified as either 2A, 2B or 3. PAHs are known to have a strong affinity to nucleic acid (DNA), which metabolically convert diolepoxides that lead to replication errors (Farhadian et al., 2011).

The Scientific Committee on Food (SCF) advised the monitoring of 15 PAHs in food (benz(a)anthracene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene, benzo(a)pyrene, chrysene, cyclopenta(cd)pyrene, dibenzo(a,h)anthracene, dibenzo(a,e)pyrene, dibenzo(a,h)pyrene, dibenzo(a,i)pyrene, dibenzo(a,l)pyrene, indeno(1,2,3-cd)pyrene and 5-methylchrysene) because they have shown clear carcinogenic effects in experimental animals (Zelinkova & Wenzl, 2015). However, others have suggested the measurement of benzo(a)pyrene as a marker for the occurrence of carcinogenic PAHs (Zelinkova & Wenzl, 2015). While the European Food Safety Authority (EFSA) considered PAH4 (sum of four different polycyclic aromatic hydrocarbons, named benzo[a]anthracene, chrysene, benzo[b]fluoranthene and benzo[a]pyrene) as an appropriate indicator (Lee et al., 2016). Based on the Commission Regulation of the EU, the maximum levels (MLs) of benzo(a)pyrene and PAH4 in smoked meat are 2 and 12 μg/kg, respectively (EU EC No 835/2011).

Most PAH investigations in the literature were conducted on smoked, grilled or fried meat but as far as we know no research has been carried out to evaluate the formation of PAHs by traditional Arabian cooking methods. Mandi, an Arabian steam cooking method that requires the chicken to be concealed with the heat source, is a very common cooking method in the Arab world. The heat source of mandi is usually generated by electricity, gas flame or charcoal. In this study, the formation of 13 PAHs in chicken cooked by mandi, shawayah (chicken grilled in gas or chicken rotisserie oven) and madhbi (chicken grilled on stones overlaid on charcoal) methods are assessed. The health risk assessment for adults exposed to PAHs from chicken consumption is also estimated.

2 Materials and Methods

2.1 Sampling and Sample Preparations

Five cooked chicken samples for each method (charcoal mandi, gas flame oven mandi, electric oven mandi, shawayah and madhbi) were collected from local restaurants around the city of Riyadh. Each cooked chicken sample was divided into two portions (breast and thigh). The samples were packed in aluminum foil and placed in polyethylene bags before they were trans-

Table 1: List of PAH compounds, showing which belong to PAH4 and PAH8, and their IRAC classification

PAH compounds	PAH 4	PAH 8	IRAC group
Fluorene			3
Phenanthrene			3
Anthracene			3
Fluoranthene			3
Pyrene			3
Benz(a)anthracene	✓	✓	2B
Chrysene	✓	✓	2B
Benzo(b)fluoranthene	✓	✓	2B
Benzo(k)fluoranthene		✓	2B
Benzo(a)pyrene	✓	✓	1
Dibenz(a,h)anthracene		✓	2A
Benz(g,h,i)perylene		✓	3
Indeno(1,2,3, -c, d)pyrene		✓	2B

IARC (International Agency for Research on Cancer) classification: group 1 = carcinogenic to humans, group 2A = probably carcinogenic to humans, group 2B = possibly carcinogenic to humans, group 3 = not classifiable as to carcinogenicity to humans.

ported to the lab (COMMISSION DIRECTIVE 2005/10/EC). The samples were stored at 4 ^{o}C until the day of analysis. Samples were homogenized in a Retsch GM 200 for 2-3 minutes.

2.2 Reagents and Chemicals

All solvents used in the extraction and analysis were HPLC grade. Acetonitrile was purchased from Merck (Darmstadt, Germany). Sodium Acetate with a purity of 99.99% was obtained from Merck (Darmstadt, Germany). Magnesium Sulphate, extra pure, was purchased from Scharlab (Barcelona, Spain). A PAH mixture analytical standard (PN 8500-6035) was obtained from Agilent (Foster City, CA, USA).

2.3 Sample extraction and clean-up

Sample extraction procedures were based on the method reported by Gratz et al. (2010). Five grams of homogenized sample was weighed into a 50 mL polypropylene tube. Then, 5 grams of water was added and the mixture shaken for one minute. A volume of 15ml of acetonitrile was then added to the mixture and the tube was shaken for one minute. Six grams of Magnesium Sulphate and 1.5 grams of Sodium Acetate were added to the mixture, followed by shaking for another minute. Then, the sample was centrifuged for 10 minutes at 3000 x g. The supernatant was filtered through a 0.2 μm PTFE syringe filter and transferred into the analysis vial.

2.4 Liquid Chromatography with FLD Analysis

Agilent 1200 Series liquid chromatography equipment, comprising autosampler, degasser, fluorescence detector, binary pump and column compartment, was used to analyze standards and samples. Chemstation software was used to control the operation of the equipment. PAHs were separated on a Zorbax Eclipse PAH analytical column (250mm × 4.6 mm, 5 μm particle size) at a 1.3 ml/min flow rate (Figure 1). Acetonitrile and water were used to make up the mobile

Table 2: HPLC-retention time, fluorescence detector parameters and LOQ values

PAH compounds	HPLC-retention time (min)	FLD-excitation (nm)	FLD-emission (nm)	FLD-PMT gain	LOQ (μg/kg)
Fluorene	17.685	272	335	14	1.08
Phenanthrene	19.84	248	380	12	5.87
Anthracene	22.127	248	380	12	2.15
Fluoranthene	24.516	280	470	14	8.27
Pyrene	26.158	270	385	14	2.13
Benz(a)anthracene	31.912	270	385	14	1.43
Chrysene	33.156	270	385	14	1.36
Benzo(b)fluoranthene	36.634	256	446	12	3.37
Benzo(k)fluoranthene	38.219	256	446	12	1.24
Benzo(a)pyrene	39.466	292	417	12	1.81
Dibenz(a,h)anthracene	42.205	292	417	12	4.61
Benz(g,h,i)perylene	43.728	292	417	12	5.43
Indeno(1,2,3, -c, d)pyrene	45.558	274	510	14	4.93

phase, which ran in a gradient condition. The column temperature was set at 25 ^{o}C, and the injection volume was 20 μL. The following parameters were used for the fluorescent detection: detection of multiwavelength emission (355, 380, 385, 417, 446, 470, 510 nm), excitation multiwavelength (248, 256, 270, 272, 274, 280, 292 nm) and general screening PMT gain of 12 and 14 (Table 2).

2.5 Quality control

Spiked samples were prepared and analyzed with each sample batch to ensure high accuracy and reliability. The recovery range of PAHs in the spiked samples was found to be between 70 - 120 %, and the expanded uncertainties of all measured compounds were $\leq$ 20%. For the calibration curves, the minimum acceptable correlation coefficient (r^2) was set at >0.9995 for a minimum of 3 levels. Limit of quantification (LOQ) was determined as 10 times the standard deviation of blank samples. Our laboratory is accredited under ISO 17025 for the determination of PAHs in chicken using HPLC-FLD.

2.6 Risk Assessment for dietary exposure to polycyclic aromatic hydrocarbons

Different PAH compounds have different abilities to generate a toxic effect. Therefore, toxic equivalency factors were used to calculate the toxicity equivalency quotient of benzo(a)pyrene (TEQ_{BaP}) to assess the carcinogenic risk. TEQ_{BaP} was calculated based on equation 1 (Food and Agriculture Organization of the United Nations & World Health Organization, 2006).

$$TEQBaP = \sum_{(i=1)}^{n} [Ci] \times TEFi \qquad (1)$$

Where Ci is the concentration of individual PAH compounds in chicken and TEFi is the toxicity factor recommended by Nisbet and LaGoy (1992).

The chronic daily intake (CDI) was measured based on equation 2 (United States Environmental Protection Agency, 2001).

$$CDI(TEQBaP\mu g/kg/day) = \frac{Ci \times IRi \times ED}{BW \times AT} \qquad (2)$$

Where C_i is the total TEQ level of PAH4 in the chicken samples (µg/kg) and IR_i is the average

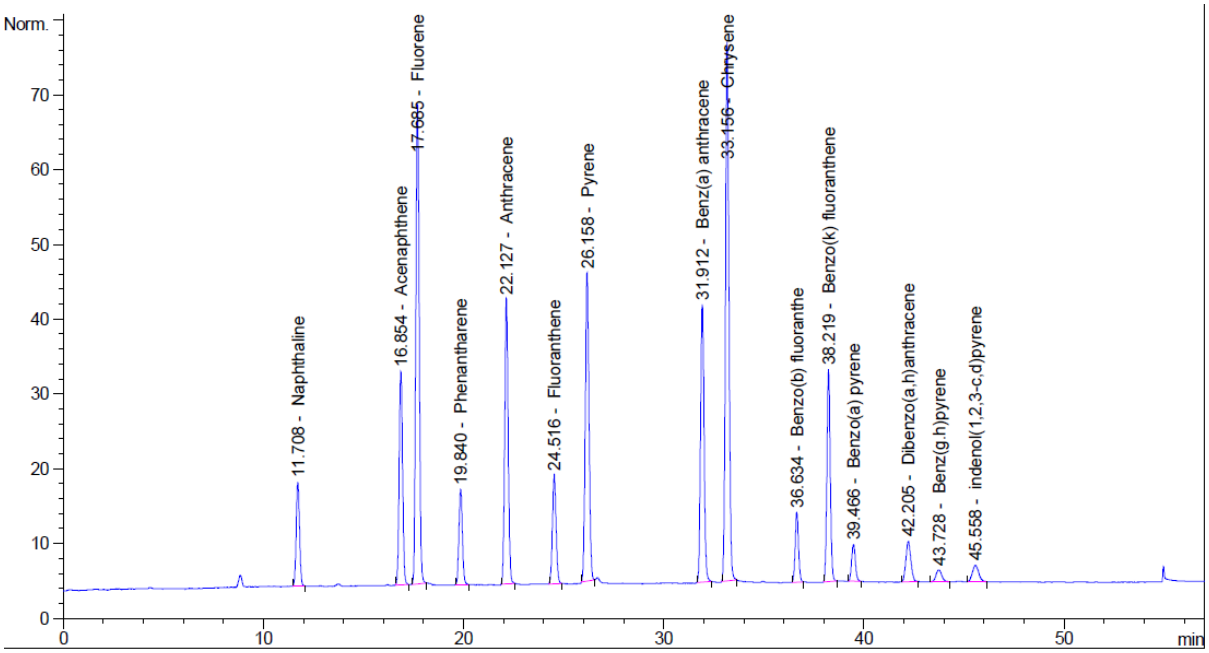

Figure 1: The chromatogram of separated PAHs by HPLC-FLD

daily intake of chicken (g/day). IR_i is estimated to be 109.6 g/day for Saudi Arabia's per capita poultry consumption in 2019 based on a report by the United States Department of Agriculture (USDA)/ Foreign Agriculture Service. BW stands for average body weight (70 kg), ED is exposure duration for adults (54 years) and AT is the average exposure time (365 day/ year $\times$75 years) (Almutairi et al., 2021).

The margin of exposure approach (MOE) is a tool used to assist risk assessors in evaluating the safety concern related to compounds present in food. This approach is followed when the compounds of interest are considered both genotoxic and carcinogenic (European Food Safety Authority, 2005). MOE was estimated based on equation 3, which is the ratio between benchmark dose lower confidence limit ($BMDL_{10}$) and chronic daily intake (CDI) (Food and Agriculture Organization of the United Nations & World Health Organization, 2009).

$$MOE = \frac{BMDL}{CDI} \quad (3)$$

Where the $BMDL_{10}$ value for PAH4 is 0.34 mg/kg bw per day (European Food Safety Authority, 2008). If the value of MOE is 10,000 or higher, this indicates a low concern for public health and a low priority for risk management actions (European Food Safety Authority, 2005).

In our study, Monte Carlo simulation was implemented to account for the uncertainty and variability of estimates (United States Environmental Protection Agency, 2001). Simulations were performed at 10,000 iterations, and health risk calculation values were reported at the 95% percentile. The analysis of variance (ANOVA), Monte Carlo simulation and other treatment of data were conducted using Microsoft Office Excel 2016.

3 Results

13 PAH compounds, namely, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenz(a,h)anthracene,

benz(g,h,i)perylene and indeno(1,2,3, -c, d)pyrene, were determined in chicken, which was cooked using different Arabian cooking methods (Table 3). The cooking methods were charcoal mandi, gas flame oven mandi, electric oven mandi, madhbi and shawayah. In the experiment, to confirm the absence of PAH compounds in uncooked chickens, four raw chicken meat samples were selected and analyzed. For descriptive analysis, a zero value was set for any compound below LOQ.

The research revealed that concentrations of PAH compounds in raw chicken samples were below LOQ, which proves absence of the targeted compounds. Fluorene and phenanthrene were found in both chicken parts (breast and thigh), which were cooked by the electric oven mandi method. The mean concentrations of phenanthrene in thigh and breast samples were 18 μg/kg and 17.23 μg/kg, respectively, with a detection rate of 100%. Moreover, fluorene was detected in breast and thigh samples with mean concentrations 5.22 μg/kg and 5.25 μg/kg, respectively.

Shawaya breast chicken meat contained phenanthrene (1.22 µg/kg) and anthracene (0.52 μg/kg). In Shawaya thigh meat, the same compounds were found but benz(a)anthracene was also detected in the thighs with a mean concentration of 0.72 μg/kg, with a detection rate of only 20%. Interestingly, in chicken cooked by gas flame oven, all targeted PAHs were below the LOQ.

The data also revealed that madhbi chicken samples were the most heavily loaded with the PAHs. In both chicken parts, phenanthrene had the highest concentration at 49.12 μg/kg in the breast and 41.81 μg/kg in the thighs. Fluorene, anthracene, fluoranthene and pyrene were also found in madbhi chicken samples, with a 100 % detection rate. The lowest concentration measured of chrysene was in madhbi breast chicken (1.05 μg/kg).

Phenanthrene, anthracene, pyrene and chrysene were found in charcoal mandi breast chicken, with mean concentrations of 8.54 μg/kg, 3.09 μg/kg, 0.77 μg/kg and 0.73 μg/kg, respectively. Also, the same compounds were detected in the thighs but with slight differences in the mean concentrations.

4 Discussion

4.1 The influence of the method of cooking on the formation of PAHs

The data obtained were evaluated by analysis of variance (ANOVA), and the difference was considered at $p \leq 0.05$. The impact of the cooking method on the formation of PAHs was investigated using different methods of cooking. The results showed that the method of cooking had a significant effect on the formation of PAHs (p-value ≤ 0.05). These findings agree with previous research conducted by Büyükkurt et al. (2020), which confirmed that food processing, food composition, type of heat source and contact with the heat source have a great effect on the concentration of PAHs formed in beef meat. Moreover, the conclusion of reviewing 7 studies showed that charcoal formed a significantly higher concentration of PAHs in cooked meat compared with gas (Ghorbani et al., 2020). In our study, madbhi chicken had the highest concentration of PAHs compared with other cooking methods. This may be attributed to the cooking style as madbhi chicken is usually cooked directly over hot stones, which leads to the increased formation of PAHs. Several research projects have been carried out on the formation of PAHs in foodstuff. Based on Alomirah et al. (2011), phenanthrene had the highest mean concentration (54.9 μg/kg) measured in various types of meat. Malarut and Vangnai (2018) detected 16 PAHs, ranging from 24.42 μg/kg to 34.07 μg/kg in sausages, which were smoked using different types of woodchips. Moreover, benzo(a)pyrene was evaluated in donor kebabs, which were cooked by different methods. The higher concentration of benzo(a)pyrene was found in doner kebabs cooked in a charcoal fire (24.2 μg/kg), compared to doner kebabs cooked in a gas fire (Terzi et al., 2008).

4.2 PAH formation in different chicken parts

PAH formation was examined in chicken thighs and breasts to determine the influence of chicken

Table 3: Mean concentration (μg/kg) of 13 PAHs in cooked chicken samples

PAH compoumds	Charcoal Mandi		Madhbi		Shawaya		Electric oven Mandi		Gas flame oven Mandi	
	Breast ± U n=5	Thigh ± U n=5	Breast ± U n=5	Thigh ± U n=5	Breast ± U n=5	Thigh ± U n=5	Breast ± U n=5	Thigh ± U n=5	Breast ± U n=5	Thigh ± U n=5
Fluorene	<LOQ	<LOQ	6.39 ± 0.72	6.32 ± 0.71	<LOQ	<LOQ	5.22 ± 0.59	5.25 ± 0.59	<LOQ	<LOQ
Phenanthrene	8.54 ± 0.99	8.10 ± 0.94	49.12 ± 5.67	41.81 ± 4.83	1.22 ± 0.14	1.28 ± 0.15	17.23 ± 1.99	18.00 ± 2.08	<LOQ	<LOQ
Anthracene	3.09 ± 0.37	1.03 ± 0.12	6.67 ± 0.79	6.06 ± 0.72	0.52 ± 0.06	1.24 ± 0.15	<LOQ	<LOQ	<LOQ	<LOQ
Fluoranthene	<LOQ	<LOQ	12.01 ± 1.48	10.29 ± 1.27	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Pyrene	0.77 ± 0.09	0.54 ± 0.07	9.26 ± 1.11	7.99 ± 0.96	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Benz(a)anthracene	<LOQ	<LOQ	3.22 ± 0.36	2.01 ± 0.22	<LOQ	0.72 ± 0.08	<LOQ	<LOQ	<LOQ	<LOQ
Chrysene	0.73 ± 0.10	0.31 ± 0.04	1.05 ± 0.15	1.08 ± 0.15	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Benzo(b)fluoranthene	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Benzo(k)fluoranthene	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Benzo(a)pyrene	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Dibenz(a,h)anthracene	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Benz(g,h,i)perylene	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Indeno(1,2,3, -c, d)pyrene	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ
Total 13 PAHs	13.12	9.98	87.72	75.57	0.87	3.23	22.45	23.25		

n stands for the number of the samples

Table 4: Estimation of MOE in adult consumers due to madhbi chicken ingestion (result below LOQ substituted by LOQ value)

			Chronic daily intake μg/kg bw /day		**MOE**	
Cooking method	**Sample portion**	**TEQBaP μg/kg**	**Mean**	**P95**	**Mean**	**P95**
Madhbi	Thigh	2.359	2.5× 10-4	3.9× 10-4	1,888,375	1,238,281
	Breast	2.480	3.4× 10-4	5.3× 10-4	1,131,575	708,811

parts on PAH formation. The results confirmed that there were no significant differences between PAH levels in the breast and thigh (> 0.05) of cooked chicken. According to Lee et al. (2020), the fat content is one of the essential factors contributing to PAH formation in meat. Under sufficient heat, fat is pyrolyzed to form PAHs, which explains the increased PAH levels detected in cooked fatty foods (Oz, 2021). Fat content in chicken breast and thigh are similar (2.22% and 2.99%, respectively), explaining the unobserved differences in PAH concentrations between breast and thigh (Edris et al., 2012). When comparing chicken with red meat, which has higher fat content, Alomirah et al. (2011) found significant variations in the concentration of PAHs between a chicken burger (13.2 μg/kg) and a red meat burger (110 μg/kg). Hence, lipid content in the samples has an evident impact on the formation of PAHs. Moisture content also plays a significant role in the formation of PAHs since it provides oxygen during heating, which prevents incomplete combustion (Lee et al., 2020).

4.3 Risk exposure of PAHs

Based on the dietary exposure assessment results, the MOE was estimated to characterize the risk of exposure to PAH4. The risk exposure of PAH4 was only measured in madhbi chicken as based on our findings, this kind of cooking method produced higher concentrations of PAHs compared to other cooking styles. The average concentration was used, and a worst-case scenario approach was also used by assigning the LOQ to all samples determined to be below the LOQ as suggested by Food and Agriculture Organization of the United Nations

Table 5: Estimation of MOE values from various studies

		Chronic daily intake ng/kg bw /day		MOE		
Country	**Foodstuffs**	**Mean**	**P95**	**Mean**	**P95**	**Reference**
Saudi	Chicken (Thigh)	0.25	0.39	1,888,375	1,238,281	This study
	Chicken (Breast)	0.34	0.53	1,131,575	708,811	
Korea	Fish and Shellfish	0.012	0.20	8,333,333	485,437	(Kim et al., 2014)
	Meat	0.290	3.90	344,828	25,634	
	Smoked products	0.038	0.37	2,631,579	265,957	
Turkey	Meat doner	1.24		274,193		(Sahin et al., 2020)
	Chicken doner	2.06		165,048		
	Grilled chicken	1.79		189,944		
France	Meat	0.040	0.066			(Veyrand et al., 2013)
	Poultry and game	0.029	0.089			
	Foodstuffs	1.4	2.99	230	113	
Denmark	grilled meat (Restaurant maximum)	48		7,08		(Duedahl-Olesen et al., 2015)
	grilled meat (Restaurant)	2.2		152		
	Home-grilled	10		33,8		
	barbecued meat	40		8,45		

and World Health Organization (2009) (Table 4). The result of the toxicity equivalency quotient of benzo(a)pyrene (TEQ_{BaP}) showed no significant difference between the TEQ_{BaP} of madhbi breast chicken (2.48 μg/kg) and madhbi thigh chicken (2.36 μg/kg) (Table 4). The 95% percentile of the CDI of PAH4 for adults in Saudi Arabia was estimated to be $5.3\times\ 10^{-4}$ μg/kg bw /day and $3.9\times\ 10^{-4}$ μg/kg bw /day for those eating madhbi breast chicken and madhbi thigh chicken, respectively.

The 95% percentile of MOE in adults due to the ingestion of madhbi chicken breasts and thighs was calculated as 708,811 and 1,238,281, respectively, which indicates no health concern. MOE values estimated in this study agreed with most published data from different countries (Table 5). Sahin et al. (2020) investigated the types and quantities of PAH compounds in doner kebabs (red meat and chicken), meatballs, grilled chicken and fish. In different heat-treated samples, the calculated MOE for PAH4 ranged between 165,048 and 274,193. In addition, Kim et al. (2014) found that the MOE for PAH4 was 485,437 for the consumption of fish and shellfish, 25,634 for the consumption of meat, and 265,957 for the consumption of smoked products in Korea. Veyrand et al. (2013) analyzed 725 foodstuffs, containing meat, consumed by the French population and found that the chronic daily intake of the 4 PAHs was low. In contrast, in Denmark, a worst-case scenario, assuming daily consumption of barbecued meat, estimated the MOE for PAH4 to be 8450 (Duedahl-Olesen et al., 2015).

5 Conclusions

PAH contamination of chicken thighs and breasts, cooked by traditional Arabian methods, was investigated using HPLC. The madhbi method was found to generate the highest levels of PAHs in comparison with other methods of cooking. Phenanthrene was the compound detected at the highest concentration in all cooking styles. There was no significant difference in the concentration of PAHs between the parts of chicken cooked with the same method. However,

the method of cooking had a significant effect on PAH formation. Therefore, it can be stated with high certainty that PAHs in chicken could be decreased by choosing the appropriate cooking method. However, the calculated MOE for adults in Saudi Arabia was found to be more than the 10,000 critical limits reported by the EFSA, indicating that the results are within a safe range.

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Experimental Study and Modelling of the Sublimation and Desorption Periods for Freeze Drying of Apple, Banana and Strawberry

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Abstract

Slices of fresh apple, banana and strawberry were frozen at -20 ^{o}C and freeze-dried using a shelf temperature of 40 ^{o}C. Theoretical expressions were proposed to predict vapor transfer kinetics during the primary and secondary drying stages. In the former, a model that predicts the sublimation rate as a function of time, considering the increasing dried layer thickness, was used, which improves greatly the sublimation time equation offered in several textbooks without adding much complexity. In the latter, an analytical solution of the unsteady state diffusion equation was applied. Permeabilities were determined for the primary drying model at an absolute pressure of about 30 Pa, though the relevant kinetic coefficient combines permeability and the mass of ice to sublime relative to the dry matter (sublimation kinetic coefficient). In the secondary drying stage, diffusion coefficients of vapor in the dried layer were in the order of 10^{-09} m^2 s^{-1} for pressures of about 3-5 Pa. In both periods, agreement of predicted and experimental values was more than satisfactory. A minimum freeze-drying time of 12, 6.8 and 8.7 h, considering a final moisture content of 4% w/w, was calculated for apple, banana and strawberry, respectively. Normalized drying curves showed a faster sublimation rate for banana, intermediate for strawberry and slowest for apple. On the other hand, desorption curves showed a faster desorption rate for apple, intermediate for banana and slower for strawberry. In each period, the ordering of the relevant kinetic coefficients (sublimation and diffusion coefficients, respectively) represented the ordering of experimental curves.

Keywords: Freeze-drying; Mathematical-model; Apple; Banana; Strawberry

1 Introduction

Freeze-drying is a physicochemical process in which water is removed from a previously frozen product by sublimation of ice during the primary drying stage, and then by desorption of the unfrozen water during the secondary period (García-Amezquita et al., 2016).

Freeze-dried products are considered of the highest quality amongst dehydrated foods due to their higher retention of bioactive compounds; besides, as they do not shrink considerably, the structure is preserved. Freeze-drying is more expensive: the process demands longer drying times with higher energy consumption, so this technique is suitable for highly value-added prod-

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Nomenclature

b	Dried layer permeability to the vapor flux, [kg $_{water}$ (m Pa s) $^{-1}$]
C_{2m}	Parameter defined in Equation (15), [m Pa kg $_{water}{}^{-1}$]
D	Water vapor diffusion coefficient in the dried layer, [m^2 s^{-1}]
F_{ice}	Frozen water fraction in the sample, [kg $_{ice}$ kg $_{initialwater}{}^{-1}$]
G	Sublimation rate per unit area in the primary drying period [kg $_{water}$ $m^{-2}s^{-1}$]
K_g	Mass transfer coefficient between sample top surface and condenser, [kg $_{water}$ (m^2Pa s) $^{-1}$]
K_s	Sublimation kinetic coefficient, [s^{-1}]
L	Thickness of material, [m]
m	Moisture content (average in sample) at time t, [kg $_{water}$ kg $_{drymatter}{}^{-1}$]
m_0	Initial moisture content, [kg $_{water}$ kg $_{drymatter}{}^{-1}$]
m_e	Final moisture content for the primary drying period, [kg $_{water}$ kg $_{drymatter}{}^{-1}$]
m_l	Local moisture content at time t, in the desorption period, [kg $_{water}$ kg $_{drymatter}{}^{-1}$]
m_{eq}	Equilibrium moisture content, [kg $_{water}$ kg $_{drymatter}{}^{-1}$]
m_{dd}	Dimensionless mean moisture content
P_{iw}	Vapor pressure of ice in the sublimation front, [Pa]
P_{sw}	Vapor pressure at the surface of the dried layer, [Pa]
P_{aw}	Vapor pressure at the condenser surface, [Pa]
P_w	Pressure at the solid-vapor interface, [Pa]
T_{lp}	Shelf temperature, [K]
T_i	Temperature of ice in the sublimation front, [K]
T_s	Dried layer surface Temperature [K]
T_{af}	Air temperature in the batch freezer [^{o}C]
T_f	Initial freezing temperature of product, [^{o}C]
t	Time, [s]
t_{sp}	Duration of the sublimation period[s]
t_{dp}	Duration of the desorption period [s]
t_{fd}	Duration of the total freeze-drying process = t_{sp}+t_{dp} [s]
x_d	Dried layer thickness, [m]
Y	Fraction of residual ice content at time t defined in Equation (8), [dimensionless]
ρ_d	Dry matter density, [kg $_{drymatter}$ m^{-3}]
ρ_f	Frozen food density, [kg m^{-3}]

ucts such as pharmaceuticals and, more recently, some foods such as strawberry (Hammami & René, 1997; Shishehgarha et al., 2002), carrot, red pepper, mushroom (George & Datta, 2002), apple (Nakagawa & Ochiai, 2015) and banana (Wang et al., 2013).

However, despite the higher investment in equipment and greater processing costs, the cultural trend for convenience and product quality favors the production of freeze-dried foods. In fact, a US-based company (Harvest Right, LLC) already sells domestic freeze-dryers. Research on this subject, however, is still insufficient (Hammami & René, 1997), particularly in freeze-drying kinetics (Shishehgarha et al., 2002). The main challenge is to mathematically model freeze-drying of foods to gain a better understanding of the phenomenon as well as to cal-

culate process time and other design-related parameters. There are some relatively simple models to estimate sublimation time (Ratti, 2012) and water content as a function of time (Hua et al., 2010). Models usually consider heat being transferred by conduction from the bottom surface of samples while vapor exits through the top surface towards the vapor condenser. In this regard, George and Datta (2002) developed and validated a mathematical model of the heat and mass transfer for the primary drying stage of carrot slices. They neglected a mass transfer coefficient between the product surface and the condenser and concluded that the overall process rate is mass transfer-controlled. These authors also studied freeze-drying of mushroom and red pepper and found that pieces of the latter dried in about 5 h, with mushroom samples being slower to dry. In another configuration, heat influx through bottom and top surfaces is considered, so the relevant models differ. El-Maghlany et al. (2019) proposed a more complex analysis for the sublimation stage, considering the transfer mechanism through pores. These authors obtained satisfactory results but their study was limited only to the first step. Sadikoglu and Liapis (1997) developed mathematical expressions for the primary and secondary stages in their study of bulk solution freeze-drying where heat transfer was by conduction from the bottom surface and by radiation from the top surface, with mass transfer upwards and vapor exiting through the top surface. On the other hand, Alfat and Purqon (2017) studied the complete freeze-drying process, considering the transfer mechanism not only in the food but also with respect to the medium. These models are complex and must be solved by numerical methods. The literature paid less attention to intermediate-complexity models which improve the sublimation time classic model offered by Karel and Lund (2003), which only calculates the duration of the sublimation period for zero ice content. In fact, the primary drying period that encompasses sublimation along with the effect of the increasing dried layer thickness was seldom modelled to predict the water content as a function of time. Besides, modelling of the secondary drying, which proceeds by desorption and diffusion of vapor through the dried layer, involves a low proportion of the original water content but a considerable fraction of the total processing time, and deserves proper attention. On these grounds, the objective of this work was to mathematically model

1. the primary drying period, with an expression accounting for sublimation and the increasing dried layer to predict the curve of moisture content vs time, and

2. the secondary or desorption period, with an analytical solution of the unsteady state diffusion differential equation.

For this purpose, a well-founded limiting moisture content between the two stages was determined from a correlation and the study encompassed three fruits: apple, banana and strawberry.

2 Materials and Methods

2.1 Preparation of samples

Slices of peeled apple (*Malus domestica*) cv. Red Delicious), banana (*Musa Paradisiaca*) and strawberry (*Fragaria x Ananassa*) were prepared, though only one type of fruit was freeze-dried in each experiment. A device made of acrylic material was used to produce 0.01 m thick slices of fresh fruit by cutting them with a sharp knife. This thickness was employed throughout. Samples were placed on 0.3 m diameter trays. In turn, these trays were covered with food grade PVC film and introduced into a batch freezer, with air at -20 ^{o}C for 24 h. The tray cover avoided some dehydration that might occur during freezing and while the samples were moved from the freezer to the freeze-dryer chamber.

2.2 Equipment description

A Rificor model L-A-B4-C freeze dryer was used (RIFICOR, Buenos Aires, Argentina, http://www.rificor.com.ar/). The equipment consists of a cylindrical vacuum chamber made of transparent acrylic, covering a stainless-steel framework in which four disc-shaped shelves, spaced 0.07 m, are held. The shelves have built-in heating

elements and a Pt-100 temperature sensor connected to an automatic temperature controller up to 50 ^{o}C. Stainless steel trays (1 mm thick, 0.3 m diameter, with a lateral wall 0.02 m high), containing samples for freeze drying, are placed on the shelves. The equipment is fitted with a Pt-100 product temperature sensor, covered by a metallic case, and connected to a digital display. The chamber pressure was measured with a Pirani gauge, and the results continuously shown in a digital display. The equipment can be observed in Figures 1 and 2.

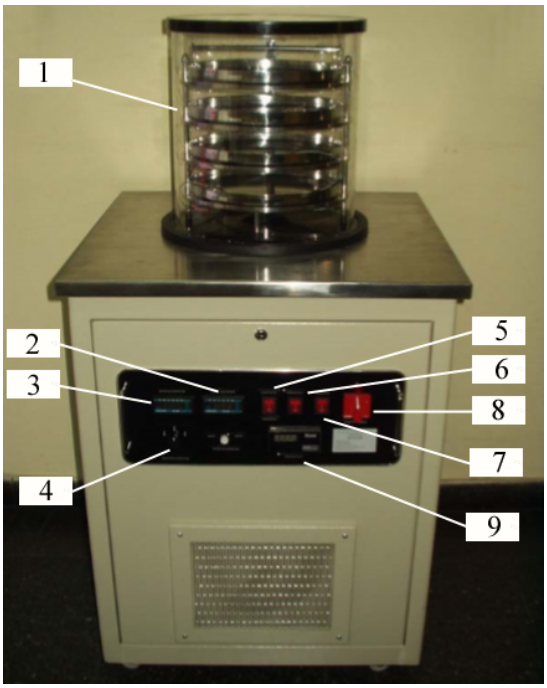

Figure 1: Rificor Freeze Dryer model L-A-B4-C. 1. Vacuum chamber; 2. Shelf temperature control; 3. Display showing either shelf, product or condenser temperature; 4. Switch to select the temperature being displayed 5. Switch that starts the condenser and its temperature measurement; 6. Switch for starting the vacuum pump and pressure gauge; 7. Switch to start heating the shelves; 8. Main switch; 9. Absolute pressure gauge.

Figure 2: Vacuum chamber of the Rificor L-A-B4-C Freeze dryer. 1. Tray; 2. Transparent vacuum chamber; 3. Temperature-controlled shelf; 4. Product temperature sensor; 5. Framework supporting the structure of the shelves under high vacuum.

2.3 Freeze-drying experiments

One tray with the frozen fruit was removed from the freezer, uncovered and placed in the freeze-dryer as the condenser temperature reached -48 ^{o}C. The cylindrical acrylic cover was put in place, and the vacuum pump was started. Chamber pressure was closely monitored and as soon as a value of 30 Pa was reached, shelf heating was switched on to set a target value of 40 ^{o}C. The saturation vapor pressure over ice at the freezing temperature is about 100 Pa, larger than the absolute pressure, and therefore much larger than the partial pressure of vapor remaining in the rarified atmosphere of the chamber thus avoiding ice melting. This last action was considered zero time for freeze-drying. To determine the experimental curve of moisture content as a function of time, triplicate experiments at 0, 1.5, 3, 4.5, 6, 8, 15, 19 and 24 h were carried out. Therefore, each experimental curve was built with 8 experiments

of different duration.
Moisture content for fresh and freeze-dried samples was determined in an Arcano (China) vacuum oven connected to a Vacuubrand PC 500 Series – CVC 3000 (Germany) diaphragm vacuum pump for 6 h at 70 ^{o}C, following the AOAC 934.06 method (AOAC International, 2016).

3 Results and Discussion

3.1 Theoretical considerations

Primary drying model: symmetrical heating from both sample surfaces

The slice of material (assumed a plane sheet) receives an inflow of heat by conduction from the shelf placed below the sample as well as heat by radiation from the upper shelf. This was inferred by observation of samples removed at early stages of preliminary freeze-drying tests: a dried layer of about the same size was observed above and below the frozen zone. Vapor, therefore, was considered to exit both through the bottom and top surfaces, and the characteristic length for vapor migration became half the initial sample thickness. Heat transfer was assumed symmetrical and so for the mass transfer rate. The scheme of mass and heat fluxes is shown in Figure 3.

The sublimation rate per unit area G, depends on the mass transfer as shown by Equation (1)

$$G = \frac{b}{x_d}(P_{iw} - P_{sw}) \tag{1}$$

Where x_d is the dried layer thickness, P_{iw} is the vapor pressure in the sublimation front and P_{sw} is the vapor pressure at the surface of the dried layer. Symbol b is the dried layer permeability to water vapor. In addition, the vapor transfer between the top surface and the condenser can be represented by:

$$G = k_g(P_{sw} - P_{aw}) \tag{2}$$

The symbol k_g stands for the mass transfer coefficient between the dried layer top surface and the condenser, which depends on equipment design and operating variables. The symbol, P_{aw} is the vapor pressure at the condenser temperature of -48 ^{o}C.

Ice temperature measured at the sublimation front were of -19, -18 and -22 ^{o}C for apple, banana, and strawberry, respectively. The vapor pressure of ice in the sublimation front was calculated by the following correlation published by Ratti (1991).

$$P_w = e^{(31.96 - \frac{6270.36}{T+273.15} - 0.461 \cdot ln(T+273.15))} \tag{3}$$

Using Equation (3), resulting values of P_{iw} for apple, banana and strawberry were 113.9, 125.2 and 85.3 Pa, respectively, for a P_{aw} of 5.0 Pa. As Equations (1) and (2) are different expressions for the same vapor flux, both can be equated as follows:

$$\frac{b}{x_d}(P_{iw} - P_{sw}) = k_g(P_{sw} - P_{aw}) \tag{4}$$

Although P_{iw} and P_{aw} keep constant in the primary drying period, P_{sw} becomes a function of the dry layer thickness x_d. By solving Equation (4) for P_{sw} we achieve the expression:

$$P_{sw} = \frac{bP_{iw} + k_g x_d P_{aw}}{x_d k_g + b} \tag{5}$$

This equation includes two parameters: b and k_g. By placing Equation (5) into Equation (2), and rearranging, the sublimation rate can be expressed in terms of the following flux equation:

$$G = \frac{P_{iw} - P_{aw}}{1/k_g + x_d/b} \tag{6}$$

Equation (6) predicts a time-varying vapor rate per unit area which is part of the transient macroscopic mass balance.
| Rate of accumulation of vapor inside the sample | = | Transfer rate through the dried layer, out of the sample and towards the condenser | The accumulation rate per unit area can be expressed as follows:

$$G = \rho_d \frac{L}{2}\frac{dm}{dt} \tag{7}$$

Where ρ_d is the density of the dry material and t is the instantaneous time. The negative sign must be written as dm/dt is inherently negative during dehydration. Where m stands for the moisture content, on a decimal dry basis, at time t. The model would be more general by

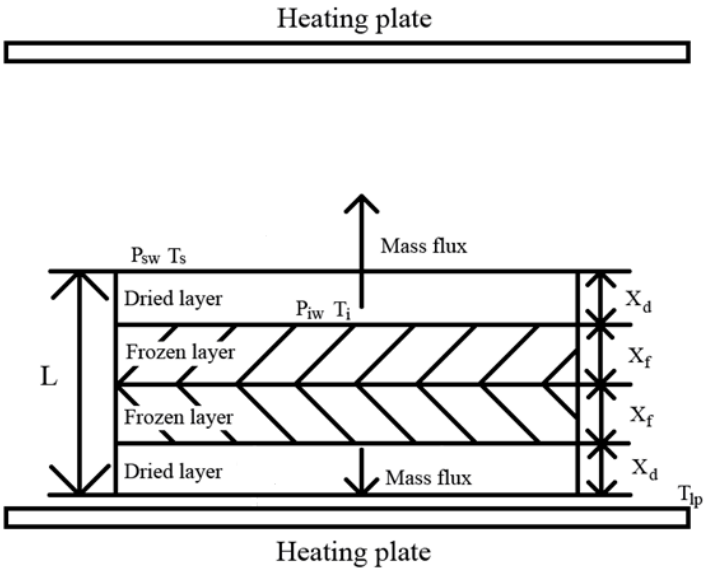

Figure 3: Schematic of freeze drying in the sample during the sublimation period.

normalizing the ratio of frozen water remaining (m - m_e) relative to the initial frozen water (m_0 - m_e) given by the expression:

$$Y = \frac{m - m_e}{m_0 - m_e} \tag{8}$$

Most models involving a dependent dimensionless variable would tend asymptotically to a limiting value, though that behavior is not expected for Y in the sublimation period, as m_e is not an equilibrium moisture content, but the maximum unfrozen water content for a freeze-dried fruit at the prevailing operating conditions. Therefore, experimental data should present a change in the drying mechanism (approximately for a time where $m \approx m_e$) from ice sublimation to water desorption.

By assuming uniform internal moisture distribution (a reasonable approximation in a sublimation front), the ratio of frozen water removed by sublimation relative to the initial frozen water content available for sublimation is 1-Y, which can be considered equivalent to the ratio of the dried layer thickness to the initial half thickness of the sample. This is represented by the following expression:

$$\frac{x_d}{L/2} = (1 - Y) \tag{9}$$

Where L is the sample thickness. Now, by differentiating Equation (8) with respect to time, a relationship is obtained between m and Y

$$\frac{dY}{dt} = \frac{dm}{dt}\frac{1}{(m_0 - m_e)} \tag{10}$$

Placing Equation (10) into Equation (7) and rearranging, the accumulation term becomes:

$$G = -\rho_d \frac{1}{2}(m_0 - m_e)\frac{dY}{dt} \tag{11}$$

The dry matter density is calculated from the value of the frozen food by assuming constant sample volume during the sublimation period, as shown in the equation below:

$$\rho_d = \frac{\rho_f}{1 + m_o} \tag{12}$$

Where ρf is the frozen food density. Now, by combining Equation (6) and (11):

$$-\rho_d \frac{L}{2}(m_0 - m_e)\frac{dY}{dt} = \frac{(P_{im} - P_{aw})}{1/k_g + x_d/b} \tag{13}$$

Now, by solving for x_d in Equation (9), placing it in Equation (13), and then multiplying both sides of the equal sign by 2/L and rearranging, the following expression is reached:

$$-\frac{dY}{dt}\frac{1-Y}{b}+\frac{2}{k_gL}=\frac{4(P_{iw}-P_{aw})}{L^2\rho_d(m_0-m_e)} \quad (14)$$

To simplify the writing, some variables kept constant during sublimation were grouped and termed C_{2m}:

$$C_{2m}=\frac{4(P_{iw}-P_{aw})}{L^2\rho_d(m_0-m_e)} \quad (15)$$

Multiplying both sides of Equation (15) by the dried layer permeability b:

$$-\frac{dY}{dt}((1-Y)+\frac{2b}{k_gL})=C_{2m}b \quad (16)$$

By integrating from Y=1 to a generic Y on the left-hand side, and from 0 to t on the right-hand side, we have:

$$\int_1^Y((1-Y)+\frac{2b}{k_gL})dY=-C_{2m}b\int_0^t dt \quad (17)$$

Multiplying both sides of the equation by (-2) and grouping part of the results in a binomial, an intermediate expression is found:

$$(1-Y)^2+\frac{4b}{k_gL}(1-Y)=2C_{2m}bt \quad (18)$$

With the purpose of grouping variables again in a binomial, the term (2b / (kg L))^2 is added at both sides of the equal sign to allow for the following equation:

$$\left(1-Y+\frac{2b}{k_gL}\right)^2=2C_{2m}bt+\left(\frac{2b}{k_gL}\right)^2 \quad (19)$$

By solving for Y, the first version of the model for the sublimation period is achieved:

$$Y=1+\frac{2b}{k_gL}-\sqrt{2C_{2m}bt+\left(\frac{2b}{k_gL}\right)^2} \quad (20)$$

To normalize experimental moisture contents (Equation (8)) to fit in Equation (20), the moisture content at the end of the sublimation period (m_e) is calculated from the fraction of unfrozen water in the previous freezing stage at -20 ^{o}C. This criterion is considered well-founded and original, and m_e does not only determine the endpoint of sublimation but also the starting point for the secondary period. To estimate the frozen water fraction, a correlation by Fikiin (1998), which is accurate for fruits, was employed:

$$F_{ice}=\frac{1.105}{1+\frac{0.7138}{ln(T_f-T_{af}+1)}} \quad (21)$$

Where F_{ice} is the fraction of frozen water in the sample, T_{af} is the air temperature in the freezer and T_f is the initial freezing temperature. Therefore, the fraction of unfrozen water, 1 – F_{ice}, can be used to calculate a delimiting moisture content between the primary and secondary drying periods.

$$m_e=m_0(1-F_{ice}) \quad (22)$$

Fitting of the sublimation model

Parameters and properties utilized here are listed in Table 1 (Choi & Okos, 1986; Quast & Karel, 1968). Experimental moisture contents and time were selected for the primary drying period, and moisture contents converted into the dimensionless variable Y as indicated by Equation (8), while Equation (20) was programmed in a user-defined MATLAB function. Equations and Figures were programmed and plotted in MATLAB 7.5.

Initial estimates for b and k_g were provided for the built-in function *nlinfit* to which the experimental data of Y vs t were supplied. The program thus written was able to determine the optimizing parameters b and k_g by nonlinear least squares, and the regression coefficient of determination, r^2. Fitted parameters for each fruit in this sublimation period are presented in Table 2. In Equation (20), two parameters of considerably different order of magnitude were obtained, and, although Table 2 shows that the expression provided accurate predictions, one must consider that the regression algorithm optimizes the parameters regardless of their physical meaning and in this sense, large variation for k_g, which makes it unreliable, and low variation for b were observed. Hence, by neglecting the external resistance to mass transfer, Equation (20) becomes:

$$Y=1-\sqrt{2C_{2m}bt} \quad (23)$$

Provided Equation (23) can maintain accurate predictions, more meaningful values of the dried layer permeability for each fruit might be determined. Fitted results of Equation (23) are presented in Table 3. A small loss of accuracy can be noticed only in apple but not in banana nor strawberry.
Now that the model has been simplified, C_{2m} can be expressed in its form of Equation (15), not to conceal the factors affecting the curve.

$$Y = 1 - \sqrt{\frac{8(P_{im} - P_{am})}{L^2 \rho_d (m_0 - m_e)} bt} \tag{24}$$

While the dried layer permeabilities, a kinetic parameter, are ordered from highest to lowest as strawberry > banana > apple, the plots of dimensionless Y vs dimensional t show the following order in drying rate: banana (fastest) > strawberry > apple (lowest). This behavior is probably due to the curve and is not explained solely by b. There are two consecutive steps: (1) sublimation of ice and (2) migration through the pores. Permeabilities explain migration but not sublimation, which can be described particularly by m_0-m_e, i.e., the mass of ice sublimed relative to the dry matter. Thus, a parameter called the sublimation kinetic coefficient k_s is defined:

$$k_s = \frac{8(P_{iw} - P_{aw})}{L^2 \rho_d (m_o - m_e)} b \tag{25}$$

This leads to the final form of the model for the sublimation period:

$$Y = 1 - \sqrt{k_s t} \tag{26}$$

Table 3 shows the values calculated for k_s. Ordering of this kinetic coefficient coincides with the order of sublimation rates of curves presented in Figure 4. Banana is less porous than strawberry though its mass of ice to sublime per kg of dry matter is also lower.
The values of b determined here for apple, banana and strawberry are comparable to the $3.5 \cdot 10^{-08}$ kg $_{water}$ (m Pa s)$^{-1}$ found by Quast and Karel (1968) in freeze-dried coffee. Values were also in the order of the $1.5 \cdot 10^{-08}$ kg $_{water}$ (m Pa s) $^{-1}$ published by Sandall et al. (1967) for turkey breast and $1.8 \cdot 10^{-08}$ kg $_{water}$ (m Pa s) $^{-1}$ as determined by Hill (1967) for beef.

Experimental data of Y vs t and predictions of the model in any of its equivalent forms (Equation (23), (24) or (26)), with the fitting parameter b for the sublimation period, are plotted in Figure 4. Calculated values follow the experimental behavior, and thus are substantially accurate for this difficult experimental system. Besides, the sublimation rate falls slightly (in absolute value) due to the influence of the increasing dried layer thickness during sublimation. This behavior was not clearly explained in the literature (Shishehgarha et al., 2002), which usually compares the sublimation period with the constant rate period that might be found in the convective drying of high-moisture foods, though the latter provides a linear behavior.

Secondary drying model

As the remaining unfrozen moisture is adsorbed on the food matrix, the vapor pressure will be lower than the value for the pure liquid at the same temperature. Some authors define this "state" as bound moisture. However, as the meaning of this concept is nebulous, we prefer to keep "adsorbed water". Then, adsorbed water must be desorbed and diffuse in the vapor state through the dried layer, exiting the sample towards the condenser. To model the secondary drying period an unsteady state mass balance was proposed, assuming the movement of vapor was governed by Fick's law of diffusion (Crank, 1975). The governing partial differential equation for a plane sheet is:

$$\frac{\partial m_l}{\partial t} = D \frac{\partial^2 m_l}{\partial x^2} \tag{27}$$

Where m_l stands for the local moisture content in the dried layer, now occupying the entire thickness of the sample, and D is the effective vapor diffusion coefficient. The initial and boundary conditions were:

$$t = 0 \qquad m_l = m_e \qquad 0 \leq x \leq L/2 \tag{28}$$

$$x = 0 \qquad \frac{\partial m_l}{\partial x} \qquad t > 0 \tag{29}$$

$$x = L/2 \qquad m_l = m_{eq} \qquad t > 0 \tag{30}$$

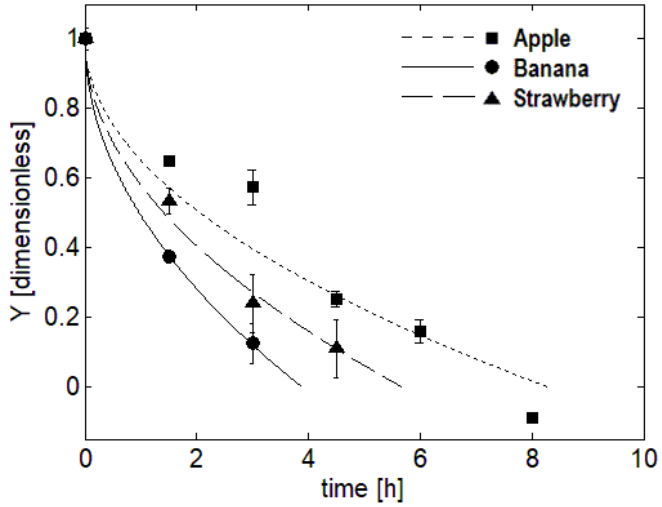

Figure 4: Experimental and predicted (Equation (26)) normalized moisture content ((m-me)/(m0-me)) as a function of time for the primary drying model. The standard deviations of data for apple, banana and strawberry are plotted as error bars.

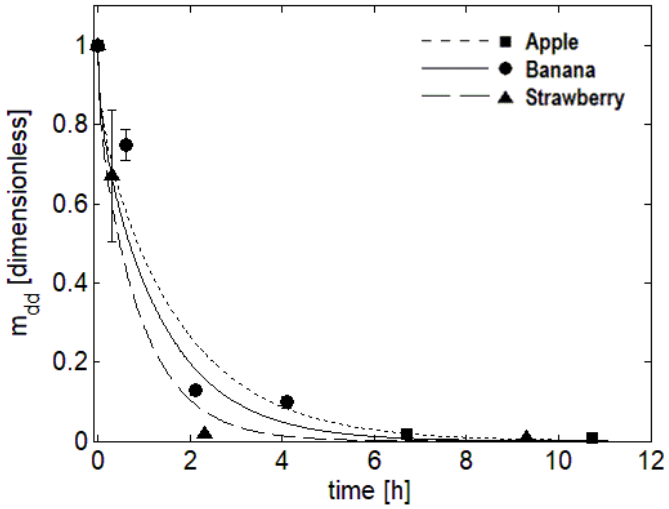

Figure 5: Dimensionless moisture content as a function of the desorption period time: apple (slower drying curve), banana (medium drying curve) and strawberry (faster drying curve). Values predicted by Eqs. (31) and (32) and experimental data with their respective standard deviations plotted as error bars.

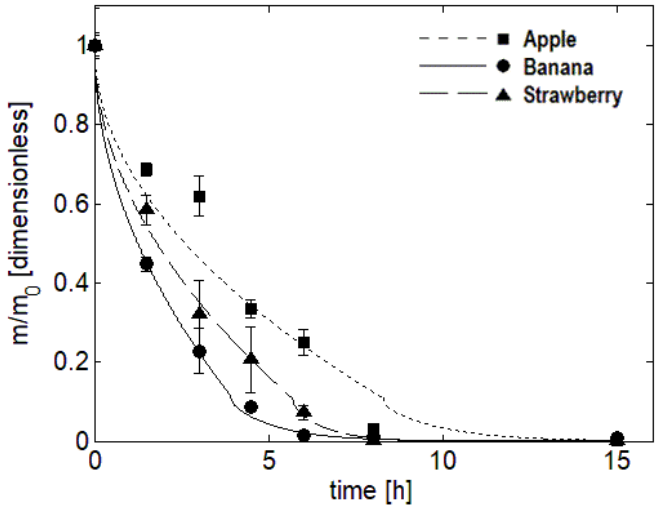

Figure 6: Normalized moisture content as a function of time for the complete freeze drying process: primary and secondary drying models. Values were predicted by Eqs. (26), (31) and (32). The standard deviations of data for apple, banana and strawberry are plotted as error bars.

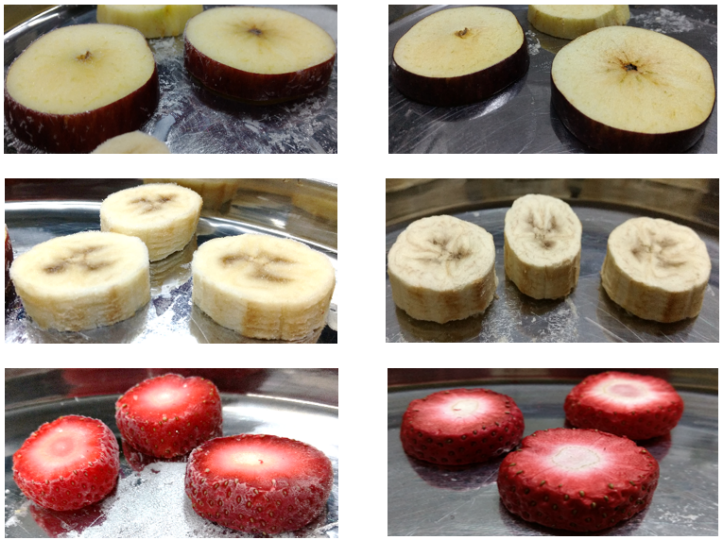

Figure 7: Frozen and freeze-dried pictures for apple, banana and strawberry: Left column for frozen fruits and Right column for freeze-dried products.

Table 1: Properties and operating conditions used to apply the sublimation drying model (Equation (21)) to the experimental data for the primary drying stage

	Apple	Banana	Strawberry
ρ_f (kg m^{-3})[a]	787	863	882
ρ_d (kg m^{-3})	116.79	214.73	88.02
m_0 (kg $_{water}$ kg $_{drymatter}$ $^{-1}$)	5.7386	3.0189	9.0208
m_e (kg $_{water}$ kg $_{drymatter}$ $^{-1}$)	0.6249	0.3529	0.9814
T_f (^{o}C)[b]	-1.45	-3.88	-1.39
T_{lp}(^{o}C)	40	40	40
L (m)	0.01	0.01	0.01
T_{af} (^{o}C)	-20	-20	-20
T_{iw} (^{o}C)	-19	-18	-22
P_{iw} (Pa)	113.9	125.3	85.3
P_{aw} (Pa)	5.0	5.0	5.0

[a] estimated by Choi and Okos (1986) equation.
[b] estimated from data published by Rahman (2008).

Table 2: Results for the primary drying period.

	Apple	Banana	Strawberry
Ice fraction during freezing (kg $_{ice}$ kg $_{initialwater}$ $^{-1}$)	0.8911	0.8831	0.8912
Duration of the sublimation period (h)	8.5 ± 0.26	4.0 ± 0.44	5.4 ± 0.58
Permeability b (kg $_{water}$ (m Pa s)$^{-1}$)	2.242E-09 ± 5.99E-11[a]	4.197E-09 ± 4.43E-10[b]	5.644E-09 ± 5.184E-10[c]
Convective mass transfer coefficient kg (kg water (m^2 Pa s)-1)	1.728E-06 ± 8.31E-7[d]	72.087 ± 18.936[e]	1.334E-05 ± 6.17E-6[f]
Coefficient of determination r^2	0.9799	0.9910	0.9532

[a,b,c] Average ± Standard Deviation (n=3) where different superscript letters on the same row are significantly different (α <0.05).
[d,e,f] Average ± Standard Deviation (n=3) where different superscript letters on the same row are significantly different (α <0.05).

Table 3: Results for the primary drying period by the simplified model (Eq (24))

	Apple	Banana	Strawberry
Ice fraction during freezing (kg $_{ice}$ kg $_{initialwater}^{-1}$)	0.891	0.883	0.891
Duration of the sublimation period (h)	8.5 ± 0.26	3.9 ± 0.34	5.5 ± 0.58
Permeability b (kg $_{water}$ (m Pa s)$^{-1}$)	2.433E-09 ± 6.020E-11^{a}	4.248E-09 ± 3.61E-10^{b}	5.538E-09 ± 5.166E-10^{c}
Sublimation kinetic coefficient k_s (s^{-1})	1.3087E-04 ± 4.1189E-6^{d}	2.8459E-04 ± 2.4620E-5^{e}	2.0193E-04 ± 2.1972E-5^{f}
Coefficient of determination r^2	0.9464	0.991	0.9502

^{a,b,c} Average ± Standard Deviation (n=3) where different superscript letters on the same row are significantly different (α <0.05).
^{d,e,f} Average ± Standard Deviation (n=3) where different superscript letters on the same row are significantly different (α <0.05).

Table 4: Results for the secondary drying period

	Apple	Banana	Strawberry
Diffusion coefficient (m^2 s^{-1})	1.628E-09 ± 2.554E-11^{a}	1.977E-09 ± 1.055E-9^{a}	2.285E-09 ± 2.213E-9^{a}
Coefficient of determination r^2	0.9999	0.9790	0.9762
Duration of the desorption stage (h)	4.3 ± 0.10	3.2 ± 1.35	3.3 ± 1.92
Duration of the freeze drying process (h)	12.8 ± 0.36	7.1 ± 1.11	8.9 ± 1.34

^{a} Average ± Standard Deviation (n=3) where different superscript letters on the same row are significantly different (α <0.05).

Table 5: Experimental values from the triplicate experiences with their respective standard deviation.

Process time [h]	Apple[a]	Banana[b]	Strawberry[c]
0	5.739 ± 0.182	3.019 ± 0.079	9.021 ± 0.871
1.5	3.943 ± 0.085	1.351 ± 0.052	5.283 ± 0.341
3	3.558 ± 0.289	0.687 ± 0.172	2.907 ± 0.758
4.5	1.917 ± 0.136	0.264 ± 0.014	1.865 ± 0.755
6	1.441 ± 0.187	0.045 ± 0.004	0.659 ± 0.164
8	0.174 ± 0.024	0.036 ± 0.005	0.016 ± 1.358E-03
15	1.116E-02 ± 2.418E-03	0.025 ± 3.911E-03	9.117E-03 ± 1.479E-03
19	6.029E-03 ± 1.169E-03	0.017 ± 7.097E-04	0.013 ± 3.251E-03
24	8.432E-03 ± 7.164E-04	0.012 ± 7.045E-05	8.729E-03 ± 1.164E-03

[a,b,c] Average ± Standard Deviation (n=3) where different superscript letters on the same row are significantly different (α <0.05). In order to improve the visualization of the Table, we omitted to place the superscripts over each value presented.

The time t is now counted from the start of the desorption period. The value of m_{eq} is the equilibrium moisture content at the operating conditions prevailing in the experiments, [kg $_{water}$ kg $^{-1}_{drymatter}$]. In the desorption period, and, because of the high vacuum conditions, this equilibrium value was assumed to be zero.

Assuming no shrinkage and constant volume (constant diffusion coefficient), Equation (27), together with the initial and boundary conditions expressed in Equations (28) to (30), can be integrated over the half volume of the sample. These assumptions are substantially met during desorption in a freeze-drying process. The analytical series solution is Crank (1975):

$$m_{dd} = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} e^{-\frac{(2n+1)^2 \pi^2 Dt}{4L^2}} \tag{31}$$

$$m_{dd} = \frac{m - m_{eq}}{m_e - m_{eq}} \tag{32}$$

Where m_{dd} is the dimensionless mean moisture content. As mentioned above, the starting moisture content in the desorption period (m_e) coincides with the final moisture content in the sublimation stage.

This combined equation was solved for the mean moisture content m for fitting to the experimental data of the secondary drying period, using a procedure already described for the sublimation period, but now to optimize parameter D. The moisture content-time data for the desorption period are not employed in the fitting of the sublimation model. The moisture content corresponding to the unfrozen water fraction, m_e is considered as a pseudo experimental point. For $m = m_e$, zero time was considered for the secondary drying. The duration of the primary period was previously calculated by the sublimation model as the time taken for moisture content to reduce from m_0 to m_e. Thus, the time used for fitting during the secondary period is the cumulative time minus the sublimation time. This is possible because the secondary drying period is assumed to start without a moisture content gradient through the thickness.

Equations (31) and (32) are written in a user-defined function file. The program module allows a variable number of terms to be employed, and the sum in Equation (31) is terminated for each time as the last term falls below 10^{-05}. With this adaptive programming, a lower number of terms are used towards the end of each fitting exercise. The optimized value of D and the goodness of fit parameters are presented in Table 4.

The coefficients of determination indicate that predictions in the secondary period were satis-

factory in general, being highly accurate in apple, accurate in banana and still very good in strawberry. All the calculations demanded only a few seconds of computing time which indicates the usefulness of the model for potential applications in control algorithms.

According to the theory of the glass transition, a critical moisture content must be defined to approach the glassy state of dry solid which results in a long-term stability of foods. For that reason, a final moisture content of 4% w/w or 0.0416 kg water kg dry matter^{-1} was used to calculate the secondary freeze-drying time. Some authors, who studied the glass transition phenomena in freeze-dried fruits, suggested a similar final moisture content which would be adequate for freeze-dried fruits' preservation at ambient temperature (Khalloufi & Ratti, 2003; Moraga et al., 2011; Mosquera et al., 2012). The total freeze-drying time is shown in Equation (33):

$$t_{fd} = t_{sp} + t_{dp} \tag{33}$$

Where t_{dp} is the duration of desorption period, t_{fd} is the length of the total freeze-drying process and t_{sp} stands for the duration of the sublimation period, all times being in s.

Predictions of the model were in fair agreement with the experimental m_{dd} as a function of time as observed in Figure 5 for the three fruits. Times were converted to h in the graph for easier visualization.

In Figure 4, the ordering of curves follows the same ordering of the sublimation kinetic coefficient k_s because, as mentioned above, it depends not only on permeability b but also on the amount of ice being sublimed relative to the dry matter. In contrast, in Figure 5, the ordering of curves occurs in the same mode as the ordering of the vapor diffusion coefficients because in the latter period the sole relevant mass transfer parameter is D. This is related to the structure and its porosity.

As moisture content at the end of the process is low and, in relative terms, is more affected by errors than values in the sublimation period, triplicate experiments are particularly useful in the desorption period and especially towards the end of it.

The diffusion coefficient determined here in apple was somewhat higher than that reported by Saravacos (1967) in the same freeze-dried fruit, $0.7 \cdot 10^{-09}$ m^2 s^{-1}, because the shelf temperature was 40 ^{o}C here compared with 30 ^{o}C in the author's study. In turn, the diffusivity for air-dried banana slices at 38 ^{o}C was $2.1 \cdot 10^{-10}$ m^2 s^{-1} which is much lower than the diffusivity for banana found in this work. On the other hand, atmospheric pressure tends to increase the diffusion coefficient but the collapsed structure of an air-dried fruit reduces this parameter markedly (Saha et al., 2018). No diffusion coefficients during freeze drying studies were found for strawberry. Interestingly, as observed in Tables 3 and 4, the ordering of permeabilities in the sublimation period coincides with the ordering of diffusion coefficients in the desorption stage (apple<banana<strawberry). This is consistent with the nature of b and D, which is related to the movement of water vapor through the porous structure of the dried layer.

Tables 3 and 4 show the most representative permeabilities and diffusion coefficients for the primary and secondary drying periods, respectively. A statistical study of analysis of variance was performed (α=0.05) to find out if the difference between the parameters obtained is significant or not. Regarding the permeability, the results showed that there was a significant difference among the values obtained for each fruit. This can be related to difference in their structure, their chemical composition and initial moisture content. These factors affect the dried layer thickness and the amount of ice per kg of dry matter and therefore impact directly on the value of b for each fruit. On the other hand, there is no significant difference between the diffusion coefficients which may be associated with the complete sublimation of ice and the movement of remaining water through the pores of the dry matter during this period. In this situation, where the moisture content is so low, it is reasonable to assume that the diffusion coefficient does not show significant differences.

Predictions of both models adapted for the moisture content dry basis, normalized by the initial moisture content as a function of time, together with the experimental data for the two periods (Equations (8), (26), (31) and (32)) are plotted in Figure 6.

In Figure 6 predictions are observed to follow the

experimental behavior substantially well. The transition between predictions of models for the primary and secondary periods can be identified by a change of slope. Continuity of moisture content between the models was ensured but not in the derivatives due to the diverse drying mechanisms in the two periods.
Finally, in Figure 7, some images of each fruit, before and after the freeze drying process are presented. As can be seen, there is little difference between the initial and final appearance for the fruits, which is one of the more attractive results of this drying methodology.

4 Conclusions

A well-founded model was developed for the sublimation drying of fruits with symmetrical mass transfer, considering the increasing dried layer to predict the remaining ice content relative to the original. The model was fitted to experimental data for apple, banana and strawberry to provide an accurate representation of the observed behavior. Dried layer permeabilities (b) were determined to be 2.3 to $5.4 \cdot 10^{-09}$ kg $_{water}$ (m Pa s)$^{-1}$, though the relevant kinetic parameter was a combination of b and the mass of sublimed ice relative to the dry matter, whose ordering was congruent with the arrangement or experimental sublimation rates. Another original feature was the use of the moisture content corresponding to the unfrozen water fraction as a limit between primary and secondary periods. A falling sublimation rate was observed and predicted for the three fruits which was caused by the increasing dried layer thickness.
The secondary drying was modelled with the analytical solution of the diffusion equation. Predictions were accurate for this low moisture content period, and allowed effective diffusion coefficients, in high vacuum, to be in the range of 1.6 to $2.9 \cdot 10^{-09}$ m^2 s^{-1}. These values are one to two orders of magnitude higher than values reported in the literature for the convective drying of fruits at atmospheric pressure. Although, the secondary drying period takes place at high vacuum, a factor that is known to reduce the diffusion coefficient, suggests the creation of a porous structure. The ordering of D in the three fruits was representative for the desorption rates in this period and coincides with the ordering of permeabilities in the sublimation period, as both parameters represent the migration of vapor through the porous structure.
In general, this two-model approach to simulate freeze drying of fruits was fairly accurate, well founded and demanded short computing time, making it suitable for use within an application as an interactive tool for freeze-dryer design and even, as part of fast-response automatic control algorithms.

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Variation of Physicochemical Characteristics of Tomato Under Different Traditional Forms of Conservation

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Abstract

Tomato is a fruit rich in vitamins and minerals, contains vitamin C and flavonoids, which prevent heart disease, strokes, chickenpox and cancer. In the world, tomato is considered as one of the main popular fresh products. Inappropriate storage can cause high losses in quantity and quality. Storage mechanisms, as well as, conservation methods can play a significant role to reduce postharvest losses by maintaining products and ingredients in an environment that protects their integrity. Drying, curing and freezing are some methods of conservation. The study evaluated the physicochemical quality of tomato, variety CAL J, exposed to different conservation techniques and environment. This study used a 2x3 factorial design with 6 treatments: A, tomato stored at room temperature (25±1^{o}C) without acidification; B, acidified tomato (pH=3.2) stored at room temperature (25±1^{o}C); C, tomato stored in a refrigerator (8^{o}C) without acidification; D, acidified tomato (pH=3.2) stored in a refrigerator (8^{o}C); E, tomato stored in an underground silo (19±1^{o}C) without acidification; and F, acidified tomato (pH=3.2) stored in an underground silo (19±1^{o}C). They were evaluated over 60 days, for moisture, titratable acidity soluble solids (^{o}Brix), and lycopene content Data were analysed with R at the 95% confidence level. Moisture ranged from 29.7% to 82.8%, ^{o}Brix 1.9 to 7.1, pH 3.17 to 4.02, titratable acidity 0.2 to 1.9% and lycopene 15.41 to 51.74 μg/g. All treatments of the tomatoes showed stability of its properties. The greatest conservation was with treatments A and B.

Keywords: Tomato; Storage; Conservation and technified processes

1 Introduction

Tomato (*Solanum lycopersicum*) is one of the most universally used fruits. This is due to the different forms of consumption and enjoyment (whole and minimally processed, salads; or processed purees, pasta, powder, ketchup, soup and canned goods), being widely cultivated throughout the world with a total annual production of approximately 186.821 million tonnes in a cultivated area of 5,051,983 hectares (Faostat, 2020). According to Brummell and Harpster (2001), over the past century, the growth in consumption of fresh fruits, in particular whole tomatoes, has led to improvements in conservation treatments to control the proliferation of post-harvest diseases and maintain the fruit quality (or flavour, colour, texture and nutritional parameters) and, consequently, extend its shelf life. These fruits have caught the attention of millions of health seekers according to Soto-Zamora et al. (2005), due to the high levels of vitamins A, E and C, β-carotene (precursor of vitamin A in the human body), fibre and phenolic compounds, namely flavonoids and phenolic acids.
When a fresh fruit is picked, the vital processes

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continue but in a different way. Plants can no longer add food or water, so they have to rely on their stored reserves. When the reserves are depleted, the fruits undergo an ageing process that leads to breakage and deterioration. They will eventually become unacceptable as food because of this natural rot. Tomatoes ripen and deteriorate rapidly at room temperature (20–25^{o}C).
Ochida et al. (2019) refer the use of low temperature storage which decreases rate of respiration, transpiration and thermal decomposition, evaporative cooling of tomato, ethylene treatment, methylcyclopropene (1-MCP), modified atmosphere packaging (MAP), drying and curing as methods that play an important role in extending tomato shelf life.
The conservation of food products aims to extend their shelf life, so that they are available for consumption without affecting the integrity and health of the consumer. Drying is one of the oldest known methods of food preservation, especially for fruits and vegetables. Its use has allowed man to delay the deterioration of biological products, for variable periods, after their physiological maturity (Almeida et al., 2016).
Various forms of treatment and storage are adopted to prevent decay, like freezing, curing and drying (Pinheiro et al., 2013). As described by Adegbola et al. (2012), the basic procedure of drying involves removal of moisture from the fruit to a point where decay is not likely. Drying can be achieved by using an oven, a dehydrator or the warm heat of the sun. Once finished, the produce should be stored in a dry place in airtight containers.
The present study aimed to evaluate the variation of the physicochemical characteristics of tomato under different forms of conservation, in order identify best practice for extending shelf life in storage.

2 Materials and Methods

A survey was conducted to discover the types of tomato storing systems used by smallholders of two different regions, Manica and Cabo Delgado. In Manica province, the survey was conducted in the Gondola district (Inchope and Gondola-sede) while in Cabo Delgado province it was conducted in Pemba-Metuge district (Nacuta and Mieze). According to MAE (2014), Gondola is located in central zone, bordering on the south with the Revué River, which separates it from the Sussundenga district; northeast with the Gorongosa district, east with the Nhamatanda district and at the southeast with the Buzi district. Gondola covers an area of 5,739 km^2 and has an estimated population of 201,735 (Instituto Nacional de Estatística, 2017), a population density of 53.8 habitants/km^2. The population is basically made up of rural families whose main livelihood activity is agriculture. Soils are basically (loam)-clay-sandy, with the main crops being maize, cassava, cowpea, sweet potato and peanuts. In livestock there is a predominance of cattle and swine.
According to MAE (2014), the district of Pemba-Metuge is located 40 km west of the city of Pemba, bordering on the north with the district of Quissanga, on the south with the district of Mecúfi, on the west with the district of Ancuabe and to the east with Pemba city. The district covers an area of 1,594 km^2 and its population was estimated at 89,122 (Instituto Nacional de Estatística, 2017). The population density is approximately 47.3 habitants/km^2 and the soils are basically sandy, washed to moderately washed. In Pemba-Metuge, agriculture is, according to same author, the dominant activity and involves almost all households. It is dominated by the production system based on the cultivation of cassava, intercropped with grain legumes such as cowpeas and peanuts. Livestock activity is complementary to agricultural activity, based on goats, cattle, chickens and ducks. The district has been affected with droughts characterized by irregular and below normal rains, which created a situation of food insecurity, requiring energetic mitigation initiatives from the District Government.

2.1 Local knowledge

Through the qualitative method of rapid ethnography and quantitative post-harvest research (Agbor & Naidoo, 2015), traditional knowledge about agricultural production and conservation methods was recovered in 200 households, where

surveys were carried out with key members of the families to identify the basic procedures for the conservation of the most produced crops. Respecting local customs, the technological adjustments were made in stages so as not to compromise the process.

2.2 Experimental procedure

In 5 replications, ripe tomatoes (variety CAL J.), were harvested manually to ensure they were free from physical damage, washed in running water, cut lengthwise in half and the seeds removed. They were then placed in a saline solution (10% NaCl) for 30 minutes, turning every 10 minutes to ensure uniform distribution of the solution, after which the tomatoes were placed on a polyethylene screen (190x180cm) at a height of 1.5 m and dehydrated at room temperature for 58 hours. Then 2 formulations were prepared: (i) by adding acetic acid (pH=3.2) to dehydrated tomato in a 1:1 ratio and (ii) dehydrated tomato with no acetic acid.

2.3 Storage

The treated tomatoes were stored under 3 conditions: room temperature (25±1 ^{o}C), (ii) underground silo (19±1 ^{o}C) and (iii) refrigerator (±8 ^{o}C) for 60 days for periodic verification of quality parameters. For laboratory analysis purposes, 750 g of each formulation were packed in 3 glass pots where (A) was defined as tomato without acidification stored at room temperature, (B), acidified tomato stored at room temperature, (C), tomato without acidification stored in a refrigerator, (D), acidified tomato stored in a refrigerator, (E), tomato without acidification stored in an underground silo and (F), acidified tomato stored in an underground silo.

2.4 Evaluation of physicochemical characteristics

The physicochemical parameters were assessed in triplicate and fortnightly for 60 days.

Moisture Content

It was determined by drying method in an oven at 105 ^{o}C, using 5 g of sample and equation 1 was used to express in percentage, according to AOAC International (2010).

$$Moisture(\%w/w) = \frac{M - M_i}{M} \times 100 \quad (1)$$

Where: M = mass of the sample taken for analysis in grams; Mi = dry sample mass in grams; w/w = weight for weight

Titratable Acidity (TA)

The titratable acidity was determined by the titration method with 0.1 N NaOH, using phenolphthalein as an indicator according to the method reported by Ganje et al. (2016), with the results expressed in % of citric acid, according to equation 2.

$$TA(\%CitricAcid) = \frac{V \times f \times m \times 0.064 \times 100}{p} \quad (2)$$

Where: V = number of mL of sodium hydroxide solution spent in the titration; p = sample mass in g or pipetted volume in mL; m = molarity of the sodium hydroxide solution (0.1 N); f = NaOH correction factor

Soluble solids content (^{o}Brix) and pH

To obtain soluble solids (Brix) a digital refractometer was used (Model 105-d) zeroed with distilled water according to Jafari et al. (2018), then a drop of the homogenised sample was placed on the refractometer for direct reading. To determine the pH, a digital pH-meter, type pH/ORP from HANNA, was used, previously calibrated with pH 7.0 and pH 4.0 buffer solutions; the readings were obtained after the electrode had been immersed in an aqueous suspension of the sample, obtained through crushing the tomato and dispersion in distilled water in the proportion 1:10.

Lycopene contents

Lycopene concentration was obtained spectrophotometrically. Acetone (40 mL) was added

to each 5.0 g sample, followed by stirring the mixture for 1 hour using a shaker (TE-1400). Then, the sample was filtered (paper Ø10) to exclude solid particles from the sample. The solids were washed with acetone for 3 more times in order to fully extract the pigments. After addition of 45 mL of petroleum ether, the samples were washed 4 more times to completely remove the acetone. The solution was then transferred to a volumetric flask, the volume made up to 100 mL with petroleum ether and the absorbance read at 470 nm, as suggested by Kakubari et al. (2020). Lycopene contents were estimated from equation 3:

$$Lycopene(\mu g/g) = \frac{(A \times V \times 1000000)}{(CE \times M \times 100)} \quad (3)$$

Where: A = absorbance of the solution at a wavelength of 470 nm, V = final volume of the solution, CE = the extinction coefficient or molar absorptivity coefficient of a pigment in a given specific solvent, M = mass of the sample taken for the analysis.

Statistical analysis

The experiment comprised a 2x3 factorial scheme in a completely randomized block design with 6 treatments, with 2 factors: acidification (2 levels) and storage (3 levels). The results were statistically analysed using analysis of variance (ANOVA) with the statistical package R at the 95% confidence level ($p < 0.05$) to identify significant differences among samples.

3 Results and Discussion

3.1 Survey of local knowledge

Table 1 represents the traditional knowledge and customs of the rural communities of Inchope, Gondola, Nacuta and Mieze on the ways of conservation and storage of tomatoes. Households stored tomatoes in 3 main ways: in polyethylene containers, maize crib and covered by leaves (room temperature). Significant differences ($p \leq 0.05$) were found in the habits and/or customs of conservation and storage in the 4 locations.

The procedures of conservation and/or storage techniques were comprised of harvesting, drying, conservation and storage (Figure 1). In Figure 1, the procedures used locally for conservation are illustrated on the left and the processing with technological adjustments on the right.

In the study carried out by Kitinoja and Kader (2015) with the aim of measuring post-harvest losses of fresh fruits and vegetables in developing countries, it was observed that traditional baskets made of palm leaves and bamboo are commonly used for conservation and management of tomato by most farmers in developing countries. Similar results were also observed in the present study; most households use this material. However, authors such as (Kangire et al., 2016), showed that the use of traditional baskets costs both small and large-scale farmers in local markets post-harvest losses ranging from 30 % - 50 %. This was also observed in the households of the present study. Other authors such as Kereth et al. (2013) and Emana et al. (2017) claim that farmers minimize physical damage to products by smoothing the inner lining of the basket and quickly adding a dampening layer of dry grass. However, grass tends to interrupt air movements, raising the temperature, which severely affects the tomato. Farmers are then recommended to use plastic boxes with holes for proper aeration. Wooden and plastic crates are the other materials that dominate packaging and transport between farmers in developing countries because they are cheap and can be constructed from locally available materials.

3.2 Physicochemical characteristics

Moisture

As shown in Table 2, moisture ranged from 20.3 to 30.78 % for treatment A; 20.3 to 89.93 % for treatment B; 20.3 to 35.6 % for treatment C; 20.3 to 89.11 % for treatment D; 20.3 to 37.43 % for treatment E, 20.3 to 94.24 % for treatment F, being statistically different ($p \leq 0.05$). It remained practically constant for treatments A, B, and a small variation with a tendency to increase for treatments C, E, F and decrease in treatment D, during the following 60 days. It was observed

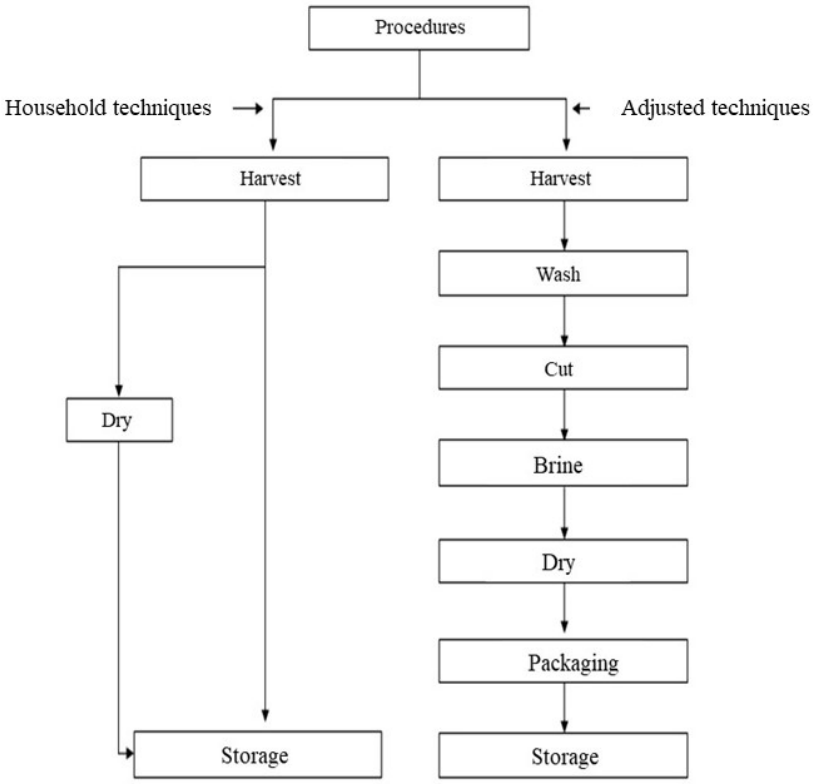

Figure 1: Traditional knowledge about post-harvest treatment of tomatoes in the villages of Inchope, Gondola, Nacuta and Mieze and technological adjustment

Table 1: Storage Systems (Maize crib, Plastic Drum and Room Temperature) used by households for food conservation in the 4 study areas (Nacuta, Mieze, Gondola and Inchope). Plastic Drum values with different superscripts significantly different (P <0.05)

Study areas	Storage systems		
	Maize Crib (%)	Plastic Drum (%)	Room temperature(%)
Mieze	92.00	42.00^{a}	4.00
Nacuta	94.00	56.00^{a}	2.00
Gondola	96.00	4.00^{b}	2.00
Inchope	94	14.00^{b}	-
p-value	*>0.05*	*<0.05*	*>0.05*

that treatments B, D, F had a higher percentage of moisture than the others, which was due to the addition of vinegar. Statistically, the treatments that received the addition of vinegar (B, D, F) were different from the others, presenting an average moisture of 82.81 % and 29.71 % of the remaining ones (A, C, F) respectively.
According to Meloni and Stringueta (2004), the desirable final moisture for dried tomatoes should be between 50 and 55 %. Different values were found in the present study and this variation was due to rehydration of the tomato from the water in the vinegar. So this can be considered a food with sufficient moisture to be consumed without rehydration. In the study carried out by Silva (2016) with the aim of to evaluate the effect of osmotic dehydration (OD), with replacement of sodium chloride (NaCl) by potassium chloride (KCl), followed by drying of the tomatoes, the moisture ranged from 15.91% to 69.49 % in the different treatments with an average of 25 %. The same average range was found in the present study, for the dried tomatoes that did not have the addition of vinegar and that were preserved at room temperature, refrigerated and underground. In the evaluation made by Alessi et al. (2013), storing dehydrated tomatoes in the solar dryer for 90 days, the moisture varied from 42.69 to 43.92 %, values that are above those found in the present study. This difference was due to the difference in solar drying method, which was a greenhouse in the case of Alessi et al. (2013) and in this study it was sunlight.

pH

The pH values are shown in table 2 for treatments A, C and E they ranged from 3.17 to 4.2. In treatments B, D and F the pH values declined in the first 15 days of storage, then stayed approximately constant throughout the remaining days of storage, a fact that is linked to the vinegar added in these treatments. Low pH values were observed in the treatment C reaching 3.17 at 45 days of storage and F reaching 3.16 and 3.17 at 30 and 45 days of storage, respectively. Statistically, the treatments that did not have added vinegar had higher pH values, averaging 3.98 compared to those with added vinegar at 3.55 ($p \leq 0.05$). It was observed that ambient temperature had a different behaviour from storage in refrigeration and in underground silo.
As reported by Silva (2016), it is generally desirable to have a pH lower than 4.5 to reduce the proliferation of microorganisms in the product. The pH in the present study was below 4.5 during the whole 60 days of storage, which would prevent the proliferation of pathogenic microorganisms and inhibit spoilage. In the study carried out by Queji and Pessoa (2011), it was observed that after the drying of Longa Vida tomatoes, the pH was below 4.5., Rodrigues et al. (2008) found that the pH that varied between 4.10 and 4.80 in tomatoes of 25 cultivars. The results of the present study are in agreement with those of Queji and Pessoa (2011).

Contents of total soluble solids

During storage, the dried tomato total soluble solids (TSS) content was significantly influenced by the preservation and the way of packaging. As presented in Table 2, treatment A had a higher value of 6.8 ^{o}Brix after 30 days of storage, as well as treatment C, which showed an increasing ^{o}Brix at 30 and 45 days of storage, with a maximum peak of 7.07 ^{o}Brix. The lowest value was observed in treatment F after 60 days of storage. Treatments A, C, and E had higher values with an average of 4.68 ^{o}Brix, whilst treatments B, D, and F had an average of 3.12 oBrix, these two groups being statistically different ($p \leq 0.05$) Refrigeration maintained the ^{o}Brix at the highest level in relation to the underground silo and ambient temperature, there being no significant difference between these latter two ($p \leq 0.05$).
Similar values were observed in the study carried out by Lacerda et al. (2016) showing a higher value (4.75 ^{o}Brix) of TSS in conventional tomato drying in relation to the other treatments which had an average of 3.77 to 3.92 ^{o}Brix in organic tomatoes. De Araujo (2018) studied the effect of storage in plastic packaging at a refrigerated location and at room temperature on tomato quality and observed that the ^{o}Brix contents of packaged and stored tomato fruits at refrigerated temperature had a lower value compared to post-season fruits, harvest and packaged and stored fruits at room temperature. The same trend was observed in the present study.

Table 2: Variation of physicochemical parameters of tomato, submitted to different forms of conservation, along the storage time (0, 15, 30, 45 and 60 days).

Treatment	Storage time (days)	Moisture (%)	pH	^{o}Brix	Titratable Acidity	lycopene (μg/g)
A	0	20.30 ± 2.61^{a}	4.15 ± 0.05^{a}	3.90 ± 0.25^{a}	0.45 ± 0.03^{a}	21.52 ± 0.50^{a}
	15	31.64 ± 0.48^{b}	4.09 ± 0.04^{a}	2.23 ± 0.05^{a}	0.15 ± 0.00^{b}	47.77 ± 0.45^{b}
	30	28.23 ± 0.83^{b}	4.02 ± 0.01^{ab}	6.80 ± 0.00^{a}	0.43 ± 0.04^{d}	22.74 ± 0.66^{c}
	45	30.81 ± 1.34^{c}	3.87 ± 0.04^{a}	5.80 ± 0.00^{b}	0.53 ± 0.03^{d}	19.39 ± 0.86^{c}
	60	30.78 ± 1.12^{d}	3.94 ± 0.05^{a}	2.23 ± 0.02^{e}	0.35 ± 0.02^{d}	16.81 ± 0.78^{e}
B	0	20.30 ± 2.61^{a}	4.15 ± 0.05^{a}	3.90 ± 0.25^{a}	0.45 ± 0.03^{a}	21.52 ± 0.50^{a}
	15	90.65 ± 0.01^{a}	3.45 ± 0.01^{b}	3.10 ± 0.00^{a}	0.38 ± 0.05^{a}	51.64 ± 0.54^{a}
	30	91.16 ± 2.32^{a}	3.39 ± 0.10^{c}	2.20 ± 0.08^{d}	1.04 ± 0.01^{c}	30.77 ± 0.71^{b}
	45	89.74 ± 0.99^{a}	3.36 ± 0.03^{b}	3.57 ± 0.05^{d}	1.58 ± 0.04^{b}	30.45 ± 0.68^{a}
	60	89.93 ± 0.72^{b}	3.52 ± 0.05^{b}	4.06 ± 0.02^{c}	0.89 ± 0.02^{c}	29.8 ± 0.30^{a}
C	0	20.30 ± 2.61^{a}	4.15 ± 0.05^{a}	3.90 ± 0.25^{a}	0.45 ± 0.03^{a}	21.52 ± 0.50^{a}
	15	33.18 ± 3.79^{b}	4.01 ± 0.05^{a}	3.97 ± 0.05^{a}	0.33 ± 0.01^{a}	31.28 ± 0.29^{d}
	30	31.63 ± 0.54^{b}	3.86 ± 0.13^{b}	6.83 ± 0.21^{a}	0.37 ± 0.01^{d}	16.74 ± 0.40^{d}
	45	33.13 ± 0.95^{bc}	3.17 ± 0.05^{b}	7.07 ± 0.09^{a}	0.53 ± 0.01^{d}	21.71 ± 0.48^{bc}
	60	35.6 ± 1.06^{c}	3.98 ± 0.05^{a}	5.03 ± 0.00^{b}	0.36 ± 0.01^{d}	22.93±0.15^{bc}
D	0	20.30 ± 2.61^{a}	4.15 ± 0.05^{a}	3.90 ± 0.25^{a}	0.45 ± 0.03^{a}	21.52 ± 0.50^{a}
	15	91.74 ± 1.12^{a}	3.54 ± 0.07^{b}	3.13 ± 0.24^{a}	0.15 ± 0.02^{b}	33.67 ± 0.15^{c}
	30	92.13 ± 0.68^{a}	3.29 ± 0.05^{c}	2.13 ± 0.19^{d}	1.22 ± 0.02^{b}	18.69 ± 0.36^{d}
	45	90.57 ± 0.83^{a}	3.87 ± 0.11^{a}	3.07 ± 0.05^{e}	1.93 ± 0.05^{a}	20.08 ± 0.26^{c}
	60	89.11 ± 0.40^{b}	3.23 ± 0.00^{c}	2.80 ± 0.00^{d}	1.65 ± 0.04^{a}	23.53 ± 0.43^{b}
E	0	20.30 ± 2.61^{a}	4.15 ± 0.05^{a}	3.90 ± 0.25^{a}	0.45 ± 0.03^{a}	21.52 ± 0.50^{a}
	15	28.97 ± 0.43^{b}	4.15 ± 0.11^{a}	3.80 ± 0.08^{a}	0.33 ± 0.02^{a}	15.41 ± 1.24^{f}
	30	27.71 ± 1.51^{b}	4.14 ± 0.05^{a}	4.73 ± 0.12^{b}	0.25 ± 0.02^{e}	24.79 ± 0.22^{b}
	45	34.78 ± 0.27^{b}	4.05 ± 0.08^{a}	4.30 ± 0.08^{c}	0.34 ± 0.03^{e}	20.81 ± 0.27^{bc}
	60	37.43 ± 0,80^{c}	3.96 ± 0.00^{a}	5.40 ± 0.01^{e}	0.36 ± 0.00^{d}	21.96 ± 0.10^{c}
F	0	20.30 ± 2.61^{a}	4.15 ± 0.05^{a}	3.90 ± 0.25^{a}	0.45 ± 0.03^{a}	21.52 ± 0.50^{a}
	15	91.85 ± 0.21^{a}	3.30 ± 0.19^{b}	3.30 ± 0.79^{a}	0.15 ± 0.01^{b}	18.82 ± 0.14^{e}
	30	92.19 ± 0.35^{a}	3.16 ± 0.05^{c}	3.23 ± 0.12^{c}	1.73 ± 0.04^{a}	47.03 ± 1.78^{a}
	45	92.61 ± 1.42^{a}	3.17 ± 0.08^{b}	2.17 ± 0.12^{f}	1.50 ± 0.01^{c}	24.65 ± 2.70^{b}
	60	94.24 ± 1.29^{a}	3.26 ± 0.50^{c}	1.93 ± 0.00^{f}	1.46 ± 0.03^{b}	19.48 ± 0.58^{d}

A, tomato stored at room temperature (25±1 ^{o}C) without acidification; B, acidified tomato (pH=3.2) stored at room temperature (25±1 ^{o}C); C, tomato stored in a refrigerator (8 ^{o}C) without acidification; D, acidified tomato (pH=3.2) stored in a refrigerator (8 ^{o}C); E, tomato stored in an underground silo (19±1 ^{o}C) without acidification; and F, acidified tomato (pH=3.2) stored in an underground silo (19±1 ^{o}C). Means + standard deviation. Values in same column and at same time with differing superscripts gave significant differences in Tukey's LSD test.

Titratable Acidity (TA)

The acidity levels in the treatments ranged from 0.15 to 1.93 %. Treatments B, D, F had the highest acidity values in relation to treatments A, C and E (Table 2). This variation was due to the added vinegar that increased acidity levels. Treatment B had an increase in pH at 30 and 45 days of storage and a decrease at 60 days of storage. The same was observed in treatments D and F. The increase between days 30 and 45 could be attributed to reactions of basic amines that form compounds with low basicity and to the oxidation of alcohols and aldehydes to acids, while for treatments A, C and E there was much less variation, as shown in Figure 1. On average the TA was 0.97% for the treatments that received the addition of vinegar at time zero.
In a study carried out by Abreu et al. (2013) aiming to evaluate the physical and chemical characteristics of canned dried tomatoes, dried tomatoes showed a wide variation of TA from 0.77% to 2.31%. Similar values were found in the present study. Palet (2012) found that there was a slight decrease in acidity from time 0 to 35 days, a slight increase from 35 days to 70 days; similar results were observed in the in the present study. The reduction of acidity may have been due to the loss of organic acids as well as the treatments. Bashir et al. (2014) had variable acidity from 0.21% to 0.45% when evaluating the effects of different drying methods on tomato quality.

Lycopene

Treatment A presented lycopene values from 17 to 48 μg/g, showing a decrease in its contents. This decrease may be associated with the incidence of sunlight. In treatment C, the amount of lycopene ranged from 17 to 31 μg/g and E presented low amounts ranging from 15 to 25 μg/g, with a tendency to increase during 60 days of storage. In treatment B, lycopene levels varied from 22 to 51 μg/g in the first 15 days of storage where the amount of lycopene increased significantly to 51 μg/g and a decline was observed in the 30 days and remained constant at 45 and 60 storage days. In D, lycopene values ranged from 19 to 34 μg/g, the amount of lycopene kept increasing after 45 days of storage (Table 2).

Shi and Le Maguer (2000) indicate isomerization and oxidation as the main causes of degradation of lycopene contents during processing and storage. In turn, the variable retention of lycopene in the treatments during storage was dependent on the presence of lighting, temperature, storage time and the bleaching done during processing. In a study carried out by Srivalli et al. (2017), it was found that there was a gradual decrease in lycopene content during 60 days of tomato powder storage due to isomerization and oxidation. Similar behaviour was observed in the present study.
O'Neill et al. (2001) found 2,718 mg. 100 g^{-1} of lycopene present, higher than found in this work, which may have been due to the varieties used and the agroecological conditions of the local of production.

4 Conclusions

In households there is a greater prevalence in the use of maize crib structures for the conservation of products. The conservation techniques employed by the households in the areas studied do not guarantee the longevity of the tomato's shelf life.
Adjustments to tomato conservation procedures allowed longer tomato shelf life, making it available for more than 60 days in times of lower abundance.
The greatest retention of physicochemical characteristics was found in treatments A, tomato stored at room temperature (25±1^{o}C) without acidification and B, acidified tomato (pH=3.2) stored at room temperature (25±1^{o}C).

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Effect of Fish Gelatin on the Characteristics of Horn Plantain Banana (*Musa paradisíaca fa. Corniculata*)-based Ice Cream

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Abstract

Ice cream is a frozen dairy product that includes healthy and nutritious aspects. To improve the value of the health benefits, it is necessary to develop functional ice cream products. One such addition is horn plantain bananas, which have the benefit of having a high dietary fibre and pectin content. In order to make ice cream, gelatin must be used as a stabilizer. The increase of non-halal gelatin has led to improvements in the production of halal gelatin derived from fish. This study was performed to evaluate the effect of adding fish gelatin to the characteristics of plantain banana (*Musa paradisiaca fa. Corniculata*)-based ice cream. This study used a pre-experimental design with a fully randomized design and one component, the addition of varying quantities of fish gelatin (A1: 0 %, A2: 0.25 %, and A3: 0.5 %) with three replicates. The characteristics (taste, fragrance, texture, and colour), melting time, and overrun were evaluated. The Duncan Multiple Range Test as post-hoc test was used to continue ANOVA-based data analysis. The results demonstrated that the inclusion of fish gelatin at various levels did not significantly alter the degree of preference for colour, fragrance, flavour, or overrun. Texture and melting time were different ($p < 0.05$). According to this study, the ice cream that the panellists preferred had an average overrun value of 52.67 ± 9.87, a melting time of 26.0 ± 0.1 minutes, and was made using the A3 formulation with 0.5 % fish gelatin.

Keywords: Ice cream; Horn Plantain Banana; Fish Gelatin

1 Introduction

Banana is one of the tropical fruit products in Indonesia that has the potential to contribute to food diversification. Bananas are one of the agricultural products with a high nutritional value but a high susceptibility to harm. The horn plantain banana is a regularly encountered and frequently consumed kind of banana (*Musa paradisiaca fa. Corniculata*) (Yangilar, 2015). The high concentration of nutritional fibre, pectin, and native resistant starch is a benefit of horn plantain bananas (Ghag & Ganapathi, 2019; Kavitha & Aparna, 2021; Li et al., 2020; Nguyen & Nguyen, 2022; Phillips et al., 2021; Safdari et al., 2021; Udo et al., 2021). Horn plantain banana contains a relatively high amount of starch and amylose, allowing it to be further developed as a functional meal. The food fibre content of horn plantain banana is 2.3 g/100 g (Octavia et al., 2017). Moreover, plantains contain fructo-oligosaccharides (FOS), which are beneficial prebiotics for the digestive system. There is 6.08 % FOS in processed horn plantain bananas. Due to the fact that plantains are included in the plantain family, horn plantain bananas have a

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higher carbohydrate content than other varieties of bananas, making them suitable for ice cream recipes (Jenie et al., 2012).

Ice cream is a frozen product used as a dessert and made from emulsified dairy ingredients, sweeteners (sucrose or dextrose), and stabilizers (Clarke, 2012; Feizi et al., 2021; Syed & Shah, 2016). Based on Indonesian Euromonitor data, retail sales of ice cream and frozen desserts in Indonesia reached US$425 million in 2021 (Euromonitor International, 2022) rising by 0.24 % from the previous year when it was worth US$424 million. This is the largest of the last five years. Food sales have been observed to have increased since the Covid-19 pandemic in 2020 (Euromonitor International, 2022). Ice creams are a rich source of fat, carbohydrates, and protein, which reflects its energy value. The energy value of standard ice cream is almost 200 kcal/100 g (Legassa, 2020). The consumer awareness of functional and healthier dairy has led to the development of new methods to produce ice cream. Ice cream is a sort of cuisine that is liked by consumers of all ages, from toddlers to adults, due to its delectable, sweet flavour and creamy consistency. Ice cream is a form of frozen cuisine created by freezing a mixture of pasteurized and homogenised milk products, sugar, stabilizers, emulsifiers, and other additives (Ntau et al., 2021). The production of ice cream requires a small quantity of gelatin stabilizer to preserve the emulsion and enhance its softness (Deosarkar et al., 2016; Istiqomah et al., 2017). Therefore, the addition of stabilizer to ice cream is necessary to produce ice cream with a soft texture, which can improve the aeration of the ice cream, reduce ice crystals growth during storage, controlling melting down, and provide uniformity of product (Bahramparvar & Tehrani, 2011; Syed & Shah, 2016). Commonly used stabilizers for ice cream are gelatin, guar gum, locust gum, alginate, carrageenan, pectin, carboxymethyl cellulose (CMC), and crystalline micro cellulose (Ayudiarti, Hastarini, & Susilowati, 2020; Ayudiarti, Suryanti, & Oktavia, 2020; Pirsa & Hafezi, 2023).

Stabilizers promote good melting of the ice cream, and provide a good texture when consumed. The best stabilizer should be harmless, readily dispersed in the ice cream, not give high viscosity and melting, be inexpensive and affordable, and not provide additional flavours (must be neutral taste) to the product (Goff & Hartel, 2013; Kamińska-Dwórznicka et al., 2022; Lestari et al., 2019; Murtaza et al., 2004; Regand & Goff, 2002). The amount and type of stabilizer used in ice cream depends on its profile. One of stabilizers used in ice cream is gelatin, because gelatin nearly tasteless and odourless with a colourless or slightly yellow appearance, so its characteristic will not affect the sensory quality of ice cream. Gelatin is a polypeptide derived from the hydrolysis of animal skin or bone collagen (Ahmad et al., 2021; Gómez-Guillén et al., 2011; See et al., 2015). The quantity of annual imports demonstrates that the demand for gelatin is growing in Indonesia. The skin and bones of cattle or pigs are used to create the raw material for imported gelatin. The utilization of raw materials derived from pig will be a difficulty for the majority-Muslim population of Indonesia, while those derived from beef will pose a problem for individuals who do not consume meat due to religious beliefs. This underpins the production of gelatin generated from fish bones and skin so that the raw materials are halal, sanitary, and acceptable to followers of other religions. The production of fish gelatin simultaneously disposes of fish fillet scraps, and the fish gelatin processing industry may be expanded to achieve high economic value and industrial competitiveness in the fisheries industry (Coppola et al., 2021; Ntau et al., 2021). Gelatin extracted from fish scale and skin is a biopolymer that contains protein up from 85% to 92%, water, and mineral salt (Alipal et al., 2021; Choi & Regenstein, 2000; Duconseille et al., 2015; Gómez-Guillén et al., 2002; Karim & Bhat, 2009).

Recent study in Indonesia, developing fish gelatin had been conducted using corkfish (*Channa striata*) (Ayudiarti, Hastarini, & Susilowati, 2020), tuna fish (Ayudiarti, Suryanti, & Oktavia, 2020), catfish (Alika & Atma, 2018), milkfish (*Chanos chanos*) (Swastawati et al., 2022), and other fish (Lestari et al., 2019). Gelatin made from these fish bones and skin has the potential to be used as a stabilizer. In addition to producing halal gelatin products at a relatively low price making it affordable, the utilization of these two raw materials can also reduce food waste, espe-

cially fish waste. Thus, the utilization of fish by-products plays an important role in economic growth and sustainable development. Studies related to the effect of adding fish gelatin as a stabilizer on the characteristics and sensory quality of banana-based ice cream are still highly limited. Therefore, this study aimed to determine the concentration of fish gelatin addition to horn plantain banana (*Musa paradisiaca fa. Corniculata*)-based ice cream and determine the characteristics and sensory quality of banana based-ice cream added with fish gelatin as a stabilizer.

2 Materials and Methods

The time frame for this research was from July to November 2022. The ice cream was made in the Nutrition Laboratory, Faculty of Health Sciences, Singaperbangsa Karawang University. The research had passed the ethical test with number 0922-09.022 /DPKE-KEP/FINAL-EA/UEU/IX/2022.

2.1 Tools, Materials, and Ice Cream Making Process

The tools needed to make catfish bone gelatin included basins, knives, pans, digital balances (Mettler Toledo), glass jars, aluminum foil, filters, beakers, calico fabric, and water baths. The tools used in making ice cream were blenders (HR2102/00, Philips, China), mixers (HR 1538/83, Philips, Indonesia), ice cream makers (ICE-1530, GEA, China), gas stoves (RI-603, Rinnai, Indonesia), spoons, thermometers (CHC445, Chenghi, China), freezer (GN-INV304SL, LG, Indonesia), pots, wooden spatulas.

The banana ice cream was made following the procedure described by Ntau et al. (2021) with modifications. The plantains, skim milk, sugar, and fish gelatin required to make plantain ice cream purchased at the local market in Karawang. Horn plantains weighed up to 500 g; fish gelatin was weighed for each treatment A1 : 0 g, A2 : 1.25 g (0.25 %), A3 : 2.5 g (0.5 %), Sugar 75 g. Non-dairy cream 100 g. Treatment A1 substituted 0.25 % carboxyl methyl cellulose (CMC), (1.25 g) for the fish gelatin. CMC was obtained from the Gunacipta Multirasa Company, Indonesia. After mixing, the mix was pasteurized for 30 minutes at 60 ^{o}C. It was then cooked and stirred for a further 30 minutes. After being poured into the designated basin, the liquid was allowed to cool for 5 minutes at room temperature. It was then elatina in the freezer for the first time for 4 hours. After this time it was removed, and the ice cream was broken up with a spoon, then homogenized using a mixer that had been set to switch number 3 for 15 minutes. It was placed in the freezer for a second time for four hours before the second homogenization. The second homogenization was carried out at the same speed setting and time as before. The ice cream mixture was then sealed in a container and frozen for 24 hours.

Analysis

This research used a pre-experimental design with a totally randomized design and one factor, the addition of varying amounts of fish elatina (A1:0 %, A2:0.25 %, and A3:0.5 %) with three repeats. The ice cream was tested for liking (taste, scent, texture, and colour), melting time, and overrun. The liking testing was undertaken by 35 qualified undergraduate nutrition students. The ANOVA data analysis was followed by a Duncan Multiple Range Test to determine where the significant elatina s were.

3 Results and Discussion

3.1 hedonic Test (Sensory Quality)

Colour

The addition of various concentrations of fish elatina to the colour of plantain ice cream did not significantly alter the colours of A1, A2, or A3 ($p>0.05$) (Table 1). The mean score of the colour parameter was between 3.80 and 4.17, as shown in Table 1 of the hedonic test findings. Therefore it was inferred that the panellists liked the manufactured ice cream items moderately to very much. These result was similar to study performed by Alika and Atma (2018). They re-

ported that the mean score of the colour parameter of ice cream with the addition of 1.2 % fish gelatin in ice cream is 3.66 and the score of hedonic test of ice cream colour was 'like slightly'. Another study performed by Ayudiarti, Suryanti, and Oktavia (2020) reported that the highest score of the colour parameters is shown by ice cream using 0.4 % fish gelatin.
Panellists favoured ice cream prepared with non gelatin because the white hue of CMC made the ice cream more vibrant than ice cream made with gelatin. Fish gelatin dissolved in water has a hazy brown hue, whereas the CMC stabilizer becomes transparent when dissolved in water, resulting in a greater degree of clarity than gelatin. The pigment from the fish skin, which has not entirely dissipated, causes the hue of the ice cream to become darker with increasing gelatin concentration (Abdel-Maqsoud et al., 2021). Product appearance, such as the colour, is a crucial attribute in consumer choice because they tend to consider the appearance more than other sensory attributes. This is because a product with a good appearance tends to be considered to have a good taste and good quality.

Aroma

There was no significant difference between A1, A2, and A3 ($p>0.05$) with regard to the scent of horn plantain banana ice cream made with fish gelatin (Table 1). The hedonic testing (Table 1) revealed that the mean score of the aroma parameter ranged from 3.71 to 3.83, with the greatest average value occurring in A1. Significantly, the typical treatment has about the same score in the category of liking the ice cream aroma. The plantain scent was more prominent than that of the added gelatin. CMC and fish gelatin do not contain volatile components, therefore they have little impact on the scent of food products to which they are added. Gelatin treatment had no effect on the aroma of ice cream, because the gelatin is tasteless and flavourless. Therefore, the smell of fish gelatin was not detected by the panellists (Regand & Goff, 2002). In a study by Swastawati et al. (2022) they reported that using 0.7 % of fish gelatin has the highest score, with a significant difference of $p\leq0.05$, whereas Ayudiarti, Suryanti, and Oktavia (2020) showed that ice cream with 0.5 % fish gelatin had the highest aroma score.

Flavour

There was no statistically significant difference ($p>0.05$) between A1, A2, and A3 in the flavour of horn plantain banana ice cream with fish gelatin (Table 1). Since gelatin merely serves as an emulsifier and has the properties of being tasteless and odourless, using fish gelatin as a stabilizer has no impact on the flavour of ice cream. The formula used for this research was not based on milk and bananas, but rather on the amount of stabilizer that was added to provide a fairly consistent sweet flavour. The use of fish gelatin as a stabilizer has no effect on the taste of ice cream because gelatin only acts as an emulsifier, and the characteristics of gelatin are that it is tasteless and odourless. Flavour in ice cream must be detected easily and provide refreshing taste in all conditions. The formula devised in this study was not based on the banana and milk content, but on the concentration of the stabilizer used so as to provide a relatively uniform sweet taste (Syed et al., 2018). Swastawati et al. (2022) showed that the flavour score with 0.7 % fish gelatin addition had the highest value and also had significant difference ($p<0.05$) from other gelatin additions. In addition, Ayudiarti, Suryanti, and Oktavia (2020) reported that the highest flavour score was given by ice cream using 0.1 % tuna gelatin while the lowest score was given by ice cream using 0.3% tuna gelatin. However the results of a Kruskall Wallis analysis of flavour parameters showed no significant difference ($p <0.05$) between treatments.

Texture

There was a considerable difference between A1 and A2, and A1 and A3 on the texture of plantain ice cream with the addition of fish gelatin (Table 1). In contrast, the addition of fish gelatin to A2 and A3 had no discernible effect on the texture of plantain ice cream. According to Table 1 of the hedonic testing, the average texture value fell between the range of 3.43 to 4.14, with A2 having the highest average value.
The consistency of ice cream is affected by the

Table 1: Hedonic Testing (sensory)

Parameter	A1	A2	A3	p
Colour	4.17 ± 0.785^a	3.94 ± 0.639^a	3.80 ± 0.632^a	0.08
Aroma	3.83 ± 0.785^a	3.80 ± 0.797^a	3.71 ± 0.926^a	0.839
Flavour	4.06 ± 0.838^a	3.60 ± 0.946^a	3.94 ± 0.906^a	0.091
Texture	3.43 ± 0.815^a	3.94 ± 0.765^b	4.14 ± 0.810^b	0.001

Note:
Values are presented as means ± standard deviation. Values with different superscript small letters on the same line differ significantly ($p<0.05$).
Scale: 1.01-2.00 = really dislike; 2.01 - 3.00 = dislike; 3.01 - 4.00 = somewhat like ; 4.01 - 5.00 = like; 5.01 - 6.00 = really like.

size of ice crystals, fat globules, air bubbles, and lactose crystals. The soft texture of ice cream is heavily determined by the composition of the stabilizer, the processing methods employed, and the storage conditions. In this study, respondents favoured ice cream with fish gelatin. This was due to the greater capacity of gelatin to bind water than CMC and its lack of syneresis, which resulted in a comparatively smoother texture of ice cream. In addition to providing products with the best adherence, these functional qualities are crucial for making goods with a pleasing texture (Feizi et al., 2021).

3.2 Overrun and melting time of ice cream

Overrun

This is the overflowing or expanding volume of the ice cream, as air is trapped in it during mixing. Air spaces will be created throughout the agitation process, and these will be released when the ice melts. Ice cream with a snowy texture will be produced as the overrun rises (spongy). The Indonesian National Standard states that the proportion of overrun for high-quality ice cream is roughly 70–80 %, compared to 50–70 % for small-scale ice cream production and 35–50 % for domestic production. The amount of stabilizer added will also affect overrun. Too much stabilizer causes the mix to become thick and tough to expand, and it is difficult for air to be incorporated into the mix.
There was no statistically significant difference ($p>0.05$) between the three ice cream formulations (Table 2). The composition A3 with 0.5 % fish gelatin had the greatest overrun percentage. This is agreed with studies conducted by Soad et al. (2014) Compared to ice cream with konjac stabilizer (66.70 %) and carrageenan (46.99 %) without the addition of emulsifier, ice cream with 0.5% gelatin stabilizer without the addition of emulsifier generated a greater overrun (77.29 %). According to El-Sisi (2014), ice cream stabilized with gelatin tends to exhibit more overrun than ice cream stabilized with chitosan.
As indicated above, one of the tasks of the stabilizer is to increase the overrun value (Bahramparvar & Tehrani, 2011). Gelatin has the characteristic of creating more overrun (Arbuckle, 1986). Gelatin is a protein stabilizer (Goff & Hartel, 2013). and is composed of both hydrophilic and hydrophobic amino acids. The hydrophilic segment binds water, whereas the hydrophobic segment attaches to air. During the process of air incorporation, it is the air that creates bubbles. A portion of the hydrophobic region will absorb surface water.

Melting Time

There are several impacts of fish gelatin on the quality of ice cream, one of which was shown in a study by Ayudiarti, Suryanti, and Oktavia (2020), in which tuna fish gelatin was used in ice cream. The inclusion of tuna fish gelatin gave a

Table 2: Overrun and melting time of ice cream

	A1	A2	A3	p
Overrun (%)	46.0 + 3.46^a	51.33 + 5.03^a	52.67 + 9.87^a	0.07
Melting time (minutes)	26.0 + 0.1^a	25.67 + 0.57^a	20.33 + 1.15^b	0.001

Note:
The one way Anova test was followed by *Duncan Multiple Range Test* (DMRT)
Values are presented as means ± standard deviation. Values with different superscript small letters on the same line differ significantly ($p<0.05$).

lower melting rate compared to beef gelatin. It was discovered in that investigation that tuna fish gelatin had a stronger viscosity and gel strength, resulting in a lower overrun value. The low overrun value boosts the resistance to melting of the ice cream.

There was a statistically significant difference ($p<0.05$) in the melting times of the three formulations as shown in Table 2. The formula without the addition of A1 gelatin had a longer melting time than the version with fish gelatin. The purpose of the stabilizer is to produce a gel in water or to combine with water so as to prevent excessive melting. In addition to the stabilizer, fat destabilization/agglomeration, viscosity, and ice crystal size influence the melting rate. Fat destabilization takes the form of clumps of fat globules that coat and encircle the air. The rise in fat clumps will increase resistance to the flow of serum (water-soluble material) as it melts and reduce the melting rate (Muse & Hartel, 2004). The hydrophobic amino acid content of African catfish bone gelatin was higher than the hydrophilic content. Therefore, the gelatin protein binds fat more strongly, reducing fat instability by making it more difficult for fat globules to comine with one another (coalescence). However, when the concentration of gelatin increases, so does the amino acid content, the amount of water bound by protein, and the total solids, causing the viscosity to increase. The melting rate of ice cream falls as the size of the ice crystals decreases (Alfaro et al., 2014).

4 Conclusions

The quantity of fish gelatin in the horn plantain banana ice cream increased the overrun value. This was inversely related to the rate of melting: the more gelatin that was added, the quicker the rate of melting. According to this study, the ice cream that the panellists preferred had an average overrun value of 52.67 + 9.87, a melting time of 26.0 + 0.1 minutes, and was made using the A3 formulation with 0.5 % fish gelatin. Higher concentrations of fish gelatin had no effect on the preferences of panellists for the colour, aroma, or flavour, but boosted their preference for texture. Their texture preference ranged from 'like slightly' to 'like'.

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A Special Issue of the International Journal of Food Studies for the 7^{th} International Iseki-FOOD Conference

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The European Association for Integrating Food Science and Engineering Knowledge Into the Food Chain (Iseki-Food) conference is a biannual event that presents an opportunity for a discussion in education, research and engagement in the food science and technology area. The organising committe aims to provide an environment to exchange ideas and experiences, establish bussiness and research relations and create collaborations.
On behalf of the Editorial Team we are announcing an special issue of the International Journal of Food Studies (IJFS) that will receive relevant applications from the conference. We are cordially inviting applications to become Editor and manuscript submissions for this Issue. Applications to become a Special Issue Editor are open for Iseki-FOOD associates. Please email your interest and details to the Editor in Chief by the 5^{th} of July 2023. The role of the Editors for this issue will be to select manuscripts of interest for the International Journal of Food Studies from the conference submissions.
Authors of approved submissions at the 7^{th} Iseki Food Conference interested will have the following schedule:

1. A call for submissions will be opened until September 2023 in the IJFS submission system
2. The peer review of the manuscripts will be reviewed between September and January 2024.
3. Typesetting, layout and production of the issue will be completed by March 2024.

From the Editorial Team of the International Journal of Food Studies we wish you a very sucessful conference!

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