Changes in Selected Food Quality Components after Exceeding the Date of Minimum Durability—Contribution to Food Waste Reduction

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Abstract: Reducing food waste throughout the agri-food chain, as well as sustainable food choices by consumers, can contribute to more efficient resource management. In addition, food insecurity (FI), a socio-economic inability to obtain appropriate quality food in sufficient amounts, still exists. To provide scientific data related to FI, i.e., by reducing food waste, the aim of this pioneering study was to evaluate selected food quality components of food at the end of the date of minimum durability and during the following 6 months of storage. Food safety and sensory attractiveness of the products were taken into consideration. Food safety measurements included microbiological quality, water activity and pH analysis. Sensory attractiveness was evaluated by the quantitative descriptive analysis (QDA) and instrumental analysis. The evaluated foodstuffs were characterised by good sensory quality and safety on the last day of minimum durability. This condition was maintained for up to 3 months of storage. However, after 6 months, significant sensory changes were found, which disqualified the products. The obtained results provide the basis for establishing guidelines that will facilitate the organisation of traders and food banks as well as consumers to make a decision not to throw food but eat or transfer it for social purposes.

Keywords: date of minimum durability; food redistribution; food safety; food security; food waste; sustainable development

1. Introduction

The safety, availability and nutrition of food rank among the fundamental needs for human life (along with personal security, potable water, warmth and shelter). The first food safety intervention techniques of cooking, smoking and salting foods contributed tremendously to human development [1]. Food safety is the absence of safe, acceptable levels of hazards in food that may harm the health of consumers [2].

The production of food has to be expanded to feed the world, but a large amount of food is wasted [3]. According to Gustavsson et al. [4], the promotion of food loss and waste reduction has a considerable potential to increase the efficiency of the whole food chain.

The prevention of food losses is of high relevance from an economic point of view [3]. Furthermore, this wasting contributes to excess consumption of freshwater and fossil fuels which, along with methane and CO_2 emissions from composting food, impacts global climate change [5].

In addition, there is a serious problem in large parts of the world, especially in developing countries, which is defined as food insecurity (FI), which means a socio-economic inability to obtain appropriate quality food in sufficient amounts [6]. This is also a problem in developed regions [7]. According to Jones [8], 3.5% of people in Europe in 2014 were considered severely food insecure (6.3% with moderate FI and 16.0% with mild FI). In North America, 4.9% of people are considered severely food insecure (6.3% with moderate FI and 10.6 % with mild FI). In Australia and New Zealand 3.3% of people are considered severely food insecure (5% with moderate FI and 11.3 % with mild FI) [8]. In the EU, 79 million EU citizens live below the poverty line [9]. In the ranking of the Global Food Security Index prepared by the Economist Intelligence Unit commissioned by DuPont, Poland was ranked 27th (113 countries) with a score of 74.1 points (100 points maximum). According to the report, 5% of the Polish population is malnourished (approximately 1.9 million people) (prevalence of undernourishment) and the intensity of food deficiency is 8 kcal/person/day (intensity of food deprivation) [10]. One solution to this problem is the donation and redistribution of unwanted or unsold food to people in need. This process of food reallocation to low-income people is called food rescue nutrition. Food redistribution is a new global trend of responding to food insecurity in developed countries [11].

The redistribution of food for social purposes, as one of the ways to reduce food waste, allows the transfer of unsold products or those whose shelf life is nearing the end to people with a low income who do not have the funds to buy them. Such activities are practiced in European countries. According to Mena et al. [12], food cooled and stored at room temperature, which is characterised by the near expiry date, in both Great Britain and Spain is transferred to social organisations. According to Garrone et al. [13], nearly 60% of surplus food in distribution results from the expiration date. On the basis of the data from 1000 commercial facilities of the hyper format and supermarkets located in Italy, it has been shown that 55% of food with a short shelf life is transferred to organisations dealing with its redistribution to needy people, 35% goes to rendering companies and 10% is used on animal feeding.

As shown by Bilska et al. [14], retail, despite the fact that it does not have the largest share in the structure of losses, is an important link in the food chain due to the significant amount of food products that can be obtained from this area and be redistributed through public benefit organisations to those in need. The level of food losses generated by all supermarkets operating in 2013 in Poland on an annual basis was estimated at 488,556 tons with a value of €837 million. According to the literature, it was assumed that 2/3 of wasted food could be used for consumption, which would mean the recovery of approximately 327 tons of food worth €552 million. Moreover, Bilska and Kołożyn-Krajewska [15] indicated that it is possible to redistribute products which are of substandard quality but are suitable for consumption, and thus reduce food waste.

One of the strategies to maintain food safety is to inform the consumer about the suitability for consumption by the appropriate information placed on the food packaging, i.e., the date of minimum durability (DMD). This means the date until which the food retains its specific properties when properly stored [16]. After the expiration date, the manufacturer no longer guarantees that the product will maintain the same quality as before this date. The research of Toma et al. [17] revealed that an understanding of the DMD has significant effects on behaviours related to lower food waste.

However, it is challenging to find the rule of balance between food waste and food safety. In order to meet both aspects, cooperation and co-development of food chain actors (consumers and authorities as well) are needed [18]. Studies that provide data on food quality, with foods which are approaching the end of the minimum durability date, are necessary for making decisions related to reducing food waste.

Therefore, to provide scientific data related to building a sustainable food system, i.e., by reducing food waste, the overall goal of this pioneering study was to evaluate selected food quality components

of food products at the end of the DMD and during the following 6-month storage. Food safety and sensory attractiveness of the products were taken into consideration.

2. Materials and Methods

2.1. Food Products Characteristic

Six food products from different groups were selected for the quality assessment. The research materials were as follows: millet (*Panicum miliaceum*), tomato concentrate, beans in tomato sauce, canned pate made from chicken, canned tuna and sweet cream. After the purchase, the research materials were stored in their original, sealed packaging and in the conditions indicated by the manufacturer on the label. There were no signs of mechanical damage to the packaging. The cans were with slightly concave ends or had flat ends, with no signs of bloating. The tested products had a "best before" designation. Their characteristics, prepared on the basis of labels, are presented in Table 1.

Table 1. The foodstuffs specification based on package information.

Foodstuff	Name; Methods of Preservation	Ingredients	Specification			
			Producer	Net Weight	Packaging Material	Other
Millet (M)	Millet; drying	millet	Kupiec Ltd., Poland	4 × 100 g	HDPE plastic perforated bag; paper box	certification of Food Safety Management Systems; ISO 9001, ISO 22000; "gluten free"
Tomato concentrate (TC)	Tomato concentrate 30%—flavours of Mediterranean cuisine; pasteurization	tomato concentrate 30%	Podravka Ltd., Poland	190 g	glass jar	-
Beans in tomato sauce (BT)	Heinz Beanz—baked beans in deliciously rich tomato sauce; pasteurization	beans (47%), tomatoes (36%), water, sugar, spirit, vinegar, modified cornflour, salt, spice extract, herb extract	H.J. Heinz Foods, Poland Ltd.	2.62 kg	3-piece steel can (recyclable material)	-
Canned tuna (CT)	Shredded tuna in oil and water pickle; sterilization	shredded tuna, soy oil (18%), water, salt	GRAAL Ltd., Poland	158 g; 131 g of fish	2-piece steel can (recyclable material)	-
Canned pate (CP)	Wielkopolski pate with poultry and peppers; sterilization	Water, pork fat, mechanically separated meat from chickens and geese (14%), chicken liver (12%), pork liver, eggs, grit from wheat, chicken hearts (3%), salt, soy protein, modified starch, peppers (0.8%), onion, species	W.W.Ż. PROFI Ltd., Poland	131 g	2-piece aluminium can	-
Sweet cream (SC)	Makro Chef; Cream—30% of fat contain; UHT sterilization	cream, carrageenan stabilizer	District Dairy Cooperative in Łowicz, Poland	1 L	carton Tetra Pak	Certification FSC (Forest Stewardship Council®)

The tested foodstuffs were thermally preserved, e.g., by sterilisation, pasteurisation or drying. The energy value, fat, carbohydrate, protein and salt content varied depending on the type of product.

According to the information on the label, some products required storage in a dry and cool place. Some products (sweet cream, tomato concentrate, beans in tomato sauce and tuna) should be stored in the refrigerator after opening. In the case of the chicken pate, the label lacked information on how to store the product after opening the package. Millet, after opening the package, should not be stored in refrigerated conditions.

All food products were tested on the end of the DMD (marked as time 0) and after 1, 3 and 6 months of storage, except for the presence of pathogens, i.e., time 0 and after 6 months. In each research period, a new product was opened. The products came from one batch. The measurements for each sample were performed in triplicate, unless otherwise stated.

2.2. Food Safety Measurements

2.2.1. Microbiological Quality

The spread plate technique on an appropriate agar medium was used to determine the number of microorganisms. The following microbiological media and test methodology were used: nutrient agar (LabM, Heywood, UK) to determine the total viable count (TVC), in accordance with the ISO 4833-2 [19], MacConkey agar No. 3 (LabM, Heywood, UK) to determine the number of rods from the *Enterobacteriaceae* family (ENT), in accordance with the ISO 21528-2 [20] and YGC agar (Sabouraud Dextrose with chloramphenicol lab Agar, Biomaxima, Lublin, Poland) to determine the number of yeasts and moulds (TYMC), in accordance with the ISO 21527-1 and ISO 21527-2 [21,22]. The number of microorganisms was expressed as the logarithm of the colony forming units per gram or millilitre (log cfu/g or mL).

The presence of pathogenic bacteria was determined using the enrichment culture method with the media indicated in the standards, such as XLD agar (Xylose Lysine Deoxycholate Agar, LabM, UK) and RAPID'Salmonella agar (Bio-Rad, Hecules, CA, USA) to determine the presence of *Salmonella*, in accordance with the ISO 6579-1 [23], and ALOA agar (Listeria according to Ottaviani and Agosti Agar, Bio-Rad, USA) and PALCAM agar (LabM, Heywood, UK) to determine the presence of *Listeria monocytogenes*, in accordance with the ISO 11290-2 [24].

2.2.2. Water Activity and pH Analysis

The measurement of the water activity (a_w) was performed using the device AQUALAB Pawkit Water Activity Meter (METER Group, Inc., Washington, DC, USA) according to the ISO 18787:2017 [25]. Only the representative samples were used for the study. They were taken immediately after opening the package of foodstuffs and placed in special, closed vials. They were kept at 25 °C for 1 h to obtain the appropriate temperature. The measurement for each sample tested was made in triplicate. The result is given as the value of the water activity together with the standard deviation.

The pH measurement was determined using an F 20 pH meter (Mettler Toledo, Greifensee, Switzerland), with a precision of up to 0.01 according to the device's manual.

2.3. Sensory Attractiveness (Sensory and Instrumental Measurements)

2.3.1. Sensory Analysis

Sensory analyses were performed by the quantitative descriptive analysis (QDA), in accordance with [26]. A team of experts took part in the selection of the sensory descriptors (characteristic attributes of odour, texture and flavour). Separate sensory attributes were defined for each tested food product (Table A1). On the basis of the above-mentioned quality characteristics, the assessing sensory panel indicated an overall sensory quality (low–high) for each sample on a separate scale. The task of the

assessors was to determine the intensity of each of the above-mentioned quality features and to put their assessment on an appropriate 10 cm scale (unstructured graphic scale; contractual units, 0–10 c.u.).

Food samples were portioned into approximately equal weights (≈10 g) and placed in plastic odourless, disposable boxes (125 mL) covered with lids. All samples were coded with three-digit codes and were passed in random order. The test samples were kept in the boxes at room temperature (22 ± 1 °C) for 30 min before analysis. The millet was boiled according to the producer's instructions, and after cooling to room temperature, it was weighed and placed in boxes for evaluation.

The assessments were undertaken with the expert panel (8 employees of the Department of Food Gastronomy and Food Hygiene at Warsaw University of Life Sciences). The panel of experts had good sensory sensitivity and were trained in the appropriate methodology of the QDA. The evaluation was carried out in two sessions and finally, 16 replications were made.

If the product showed signs of deterioration or its appearance was significantly different from the norm, only the intensity of the odour was assessed.

2.3.2. Texture Analysis

Tomato concentrate flow limit: the measurement (N/m^2) was made using a Brookfield DV3T rotational viscometer (Brookfield Eng. Lab., Inc., Middleboro, MA, USA). The following parameters were used: test speed; 5 rpm, and measurement temperature; 20 ± 1 °C (according to the manufacturer's instructions). The analysis was carried out using a V-73 spindle at a test speed of 5 rpm. The measurement was performed in triplicate and the arithmetic mean was taken as the result.

Canned tuna, beans in tomato sauce, millet hardness: the preserved tuna, beans in tomato sauce and millet samples were analysed using a TA.XT Plus Analyzer (Stable Micro Systems, Godalming, UK). The hardness was determined using a P/36R head at a test speed of $2 \text{ mm} * \text{s}^{-1}$. The measurement was performed in five replications, and the arithmetic mean was taken as the result.

Canned pate hardness: the preserved pate samples were analysed using a TA.XT Plus Analyzer (Stable Micro Systems, Godalming, UK). The hardness was determined using a ring, with a head diameter of 45 mm at a test speed of $3 \text{ mm} * \text{s}^{-1}$. The measurement was performed in five replications, and the arithmetic mean was taken as the result.

2.3.3. Viscosity

Viscosity of sweet cream: the measurement (N/m^2) was made using a Brookfield DV3T rotational viscometer (Brookfield Eng. Lab., Inc., Middleboro, MA, USA) at a constant shear rate (150 rpm/min), and the measurement temperature was 20 ± 1 °C (according to the manufacturer's instructions). The analysis was carried out using an HA-02 spindle.

2.3.4. Colour Determination (*L*a*b* Parameters)

The characterisation of the products' colour was performed using the *L**, *a** *b**/ system proposed by the International Commission on Illumination (CIE) in the work of Papadakis et al. [27]. *L** refers to the luminosity or lightness component, and *a** (intensity of red (+) and green (−)) and *b** (intensity of yellow (+) and blue (−)) are the chromaticity coordinates. All sampled instant noodles were analysed in terms of the referred parameters using a Minolta CR-310 colourimeter (Konica-Minolta, Osaka, Japan) that was previously calibrated with a white standard tile (according to the manufacturer's instructions). Five repetitions were made for each measurement.

2.4. Statistical Analysis

A one-way ANOVA with a linear model was implemented to analyse the data from the microbiological, physico-chemical, instrumental (texture and colour analysis) and sensory tests. A Bonferroni correction was applied to all ANOVA results. Additionally, the results of the QDA were assessed based on the principal component analysis (PCA). The statistical significance was recognised when $p < 0.05$. All tests were performed using the STATISTICA 13.1 PL software (StatSoft, Kraków, Poland).

3. Results

3.1. Food Safety Characteristic

3.1.1. Microbiological Quality

Table 2 presents the results of the microbiological evaluation of the tested products. Pathogenic bacteria, harmful for human health and life, i.e., *Salmonella* spp. and *Listeria monocytogenes*, were not found in all the tested samples. The time of storage significantly influenced the number of tested microorganisms ($p < 0.05$).

Table 2. Microbiological quality of the tested products during storage.

Product	Time [Month]	Number of Bacteria [log cfu/g or mL]			Presence of	
		ENT [1]	TVC [2]	TYMC [3]	SAL [4]	LM [5]
Millet	0	2.95 ± 0.89 [AB]	3.10 ± 0.36 [A]	2.77 ± 0.08 [A]	Nd [6]	nd
	1	1.32 ± 0.55 [B]	2.48 ± 0.41 [A]	2.25 ± 0.48 [AB]	- [7]	-
	3	1.36 ± 0.39 [AB]	2.50 ± 0.15 [A]	3.14 ± 0.39 [A]	-	-
	6	1.20 ± 0.17 [B]	4.36 ± 0.37 [B]	3.33 ± 0.29 [ABC]	nd	nd
Tomato concentrate	0	1.85 ± 0.80 [A]	1.60 ± 0.52 [A]	<1.00 [A]	nd	nd
	1	<1.00 [B]	1.78 ± 0.34 [A]	<1.00 [A]	-	-
	3	2.02 ± 0.26 [A]	2.02 ± 0.50 [A]	<1.00 [A]	-	-
	6	<1.00 [AB]	2.99 ± 0.49 [B]	<1.00 [A]	nd	nd
Beans in tomato sauce	0	<1.00 [A]	2.74 ± 0.36 [A]	3.05 ± 0.06 [A]	nd	nd
	1	<1.00 [A]	2.00 ± 0.89 [A]	1.20 ± 0.17 [B]	-	-
	3	<1.00 [A]	<1.00 [A]	1.00 ± 0.00 [B]	-	-
	6	<1.00 [A]	<1.00 [B]	<1.00 [C]	nd	nd
Canned tuna	0	1.72 ± 0.58 [A]	1.07 ± 0.92 [A]	<1.00 [A]	nd	nd
	1	2.21 ± 0.50 [A]	2.35 ± 0.16 [A]	1.87 ± 0.32 [B]	-	-
	3	2.72 ± 0.22 [A]	2.72 ± 0.16 [B]	<1.00 [A]	-	-
	6	<1.00 [B]	1.86 ± 0.22 [A]	<1.00 [A]	nd	nd
Canned pate	0	<1.00	4.40 ± 0.36 [A]	3.54 ± 0.14 [A]	nd	nd
	1	<1.00	1.00 ± 0.00 [A]	<1.00 [B]	-	-
	3	<1.00	<1.00 [B]	<1.00 [B]	-	-
	6	<1.00	<1.00 [B]	<1.00 [B]	nd	nd
Sweet cream	0	2.30 ± 0.27 [A]	1.69 ± 0.43 [A]	1.93 ± 0.18 [A]	nd	nd
	1	<1.00 [A]	<1.00 [B]	1.20 ± 0.17 [A]	-	-
	3	<1.00 [A]	<1.00 [AB]	<1.00 [B]	-	-
	6	<1.00 [A]	<1.00 [BC]	<1.00 [B]	nd	nd

[1] *Enterobacteriaceae*; [2] the total viable count; [3] the number of yeasts and moulds; [4] *Salmonella*; [5] *L. monocytogenes*; [6] nd: not detected; [7] not tested; ± standard deviation; means followed by different capital letters A–C within the same sample are significantly different ($p < 0.05$); (n = 3).

The number of bacteria from the *Enterobacteriaceae* family was low in the samples of millet. On the date of the minimum durability, it was less than 3.00 log cfu/g. Other indicators of microbiological quality, i.e., TVC and TYMC, were at a similar level. Compared to the other tested products, the millet contained the highest number of microorganisms and at the same time the lowest water activity (Table 3). This contradiction was due to the type of packaging. In the case of millet, it was not hermetic and did not constitute a sufficient barrier to factors favouring the development of microorganisms.

Table 3. Water activity and pH of tested food products during storage.

Product	Time (Month [1])	Water Activity (a_w)	pH
Millet	0	0.23 ± 0.01 [A]	- [2]
	1	0.37 ± 0.01 [BC]	-
	3	0.38 ± 0.00 [BC]	-
	6	0.52 ± 0.02 [B]	-
Tomato concentrate	0	0.96 ± 0.01 [A]	4.26 ± 0.02 [A]
	1	1.00 ± 0.00 [B]	4.23 ± 0.02 [A]
	3	0.99 ± 0.01 [A]	4.25 ± 0.04 [A]
	6	0.99 ± 0.01 [A]	4.53 ± 0.03 [A]
Beans in tomato sauce	0	1.00 ± 0.00 [A]	5.13 ± 0.02 [A]
	1	1.00 ± 0.00 [A]	5.14 ± 0.03 [A]
	3	1.00 ± 0.00 [A]	5.12 ± 0.02 [A]
	6	0.99 ± 0.00 [A]	5.12 ± 0.01 [A]
Canned tuna	0	1.00 ± 0.00 [A]	6.09 ± 0.02 [A]
	1	1.00 ± 0.00 [A]	6.09 ± 0.02 [A]
	3	1.00 ± 0.00 [A]	6.10 ± 0.02 [A]
	6	1.00 ± 0.00 [A]	6.08 ± 0.02 [A]
Canned pate	0	0.99 ± 0.01 [A]	6.07 ± 0.07 [A]
	1	0.99 ± 0.01 [A]	6.03 ± 0.06 [A]
	3	0.97 ± 0.01 [A]	6.03 ± 0.05 [A]
	6	0.97 ± 0.00 [A]	6.03 ± 0.02 [A]
Sweet cream	0	0.99 ± 0.00 [A]	4.52 ± 0.61 [A]
	1	0.99 ± 0.00 [A]	4.51 ± 0.03 [A]
	3	0.99 ± 0.00 [A]	4.52 ± 0.04 [A]
	6	0.99 ± 0.00 [A]	4.53 ± 0.03 [A]

[1] 0: analysis on the DMD; 1: analysis after 1 month from the DMD; 3: analysis after 3 months from the DMD; 6: analysis after 6 months from the DMD; [2] not tested; values denoted by different capital letter in superscripts in the same column differ significantly during storage of each product ($p < 0.05$); (n = 3).

A small number of bacteria from the *Enterobacteriaceae* family (maximum 2.02 log cfu/g), TVC (maximum 2.99 log cfu/g) and yeasts and moulds were found in the tomato concentrate.

The number of bacteria from the *Enterobacteriaceae* family was very low or below the detection level in the beans in tomato sauce. The total number of microorganisms as well as the number of yeasts and moulds was low and around 3 log cfu/g.

In the canned tuna, there was a limited number of bacteria of the family *Enterobacteriaceae* and a low TVC (1.07-2.72 log cfu/g) was observed. The number of yeasts and moulds was also low or below the detection threshold.

Bacteria from the *Enterobacteriaceae* family were not found in the canned pate. On the DMD, a fairly high total number of microorganisms (4.40 log cfu/g) and yeasts and moulds were found. However, the samples tested after 1 month from the DMD contained these microorganisms at the threshold of detection.

A trace number of the *Enterobacteriaceae* family, total number of microorganisms and number of yeasts and moulds were found in the sweet cream.

3.1.2. Water Activity and pH Analysis

The water activity is understood as the ratio of the vapour pressure above the surface of the solution to the pressure above the surface of chemically pure water at the same atmospheric pressure and temperature [28].

The values of the water activity of the studied food products are presented in Table 3. The water activity of the millet was 0.23 at time 0 and increased during 6 months of storage ($p < 0.05$), which indicates the influence of environmental conditions on the millet. Nevertheless, this was the only

product which had maintained an a$_w$ below 0.6 and the risk of microbial growth is low, so the hermetic packaging was not required.

The pH values of the tested food products are placed in Table 3. The parameter was characteristic for each type of product and did not change significantly during storage ($p > 0.05$).

3.2. Sensory Attractiveness (Sensory and Instrumental Characteristics)

3.2.1. Sensory Quality

The basic assumption in the QDA method is that flavour, odour and texture are not individual quality features of the product, but a complex of many individual features that can be distinguished, identified and determined on their intensity [26].

The sensory profiles of the studied food products on the DMD and after 1, 3 and 6 months from the DMD are presented in Figures A1–A6. Generally, the time of storage significantly influenced the sensory descriptors in all tested samples ($p < 0.05$) but was different in the individual samples.

During the storage, the intensity of the products' characteristics usually increased. For example, the intensity of grain flavour of the millet samples 6 months after the DMD was more substantial ($p < 0.05$) (Figure A1). However, despite the variability of the assessed features, the overall quality was rated at a high level, usually above 5.5 c.u. This component of the product's sensory profile indicates that the differentiators were well harmonised [29].

The sensory evaluation of the tested food carried out in accordance with the QDA method can provide comprehensive and detailed knowledge about the sensory profile of the product, while the use of PCA analysis can significantly explain the direction of changes arising during storage by creating subsets of variables that are correlated with each other. This approach will allow one to limit the number of discussed factors, indicating those that most condition the sensory profile of the assessed foodstuffs [29].

An analysis of the data made it possible to identify five principal components (PC) which explain the 81% initial variability of the millet on the DMD and five PCs which explain the 88.8% initial variability of the product stored for 6 months.

Given the millet samples (Figure 1a), on the basis of the close positions of the discriminant vectors for the boiled millet's odour and flavour (vectors 1 and 8), and the overall quality (vector 15), it can be concluded that there is a positive correlation between these variables. However, the greatest negative impact on the overall sensory quality was caused by sweet odour and flavour (vectors 4 and 10), and also storage flavour (vector 13). For the three other factors, the correlation was observed in stickiness (factor 3), colour (factor 4) and other flavours (factor 5). After 6 months of storage (Figure 1b), a positive impact on the overall quality of the boiled millet's odour and flavour (vectors 1 and 8) was observed. However, irritating and other odours (vectors 3 and 5), and storage flavour (vector 6) had a negative impact on the overall quality of the millet. For the three other factors, the correlation was observed for the following sensory features: stickiness (factor 3), bitter and storage flavour (factors 4 and 5).

Due to the lack of complete data from the 6 months of the tomato concentrate's storage, the principal component analysis was performed for data up to the 3-month mark. During analysis, the four PCs which explain the variability of the tomato concentrate's characteristics by 83.4% and five PCs which explain the 88.8% initial variability of the stored product were determined. On the DMD, tomato odour and flavour (vectors 1 and 8), and sweet odour (vector 2) as well as sour flavour (vector 10) positively correlated with the overall quality (vector 14). A negative correlation was detected with other odour and flavour (vectors 4 and 13). For the two other factors, a correlation was observed for acetic flavour (factor 3) and colour (factor 4). After 3 months of storage, tomato odour and flavour (vectors 1 and 8), and additionally thickness (vector 7) positively correlated with the overall quality. However, flavours such as tart, acetic and other (vectors 11–13) were unfavourable. For the two other factors, the greatest correlation was observed for colour (factor 3) and sweet odour (factor 4) (Figure 2).
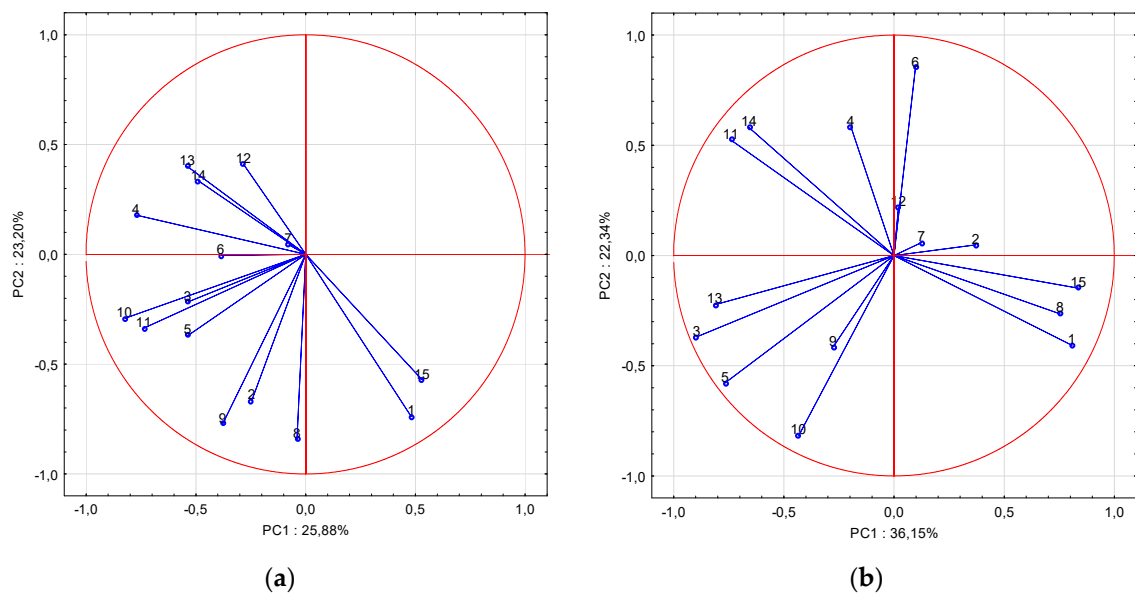
Figure 1. Principal component analysis graphs of the sensory evaluation of (**a**) the millet on the DMD and (**b**) after 6 months of storage past the DMD; o: odour; f: flavour; 1 boiled millet o.; 2 grain o.; 3 irritating o.; 4 sweet o.; 5 other o.; 6 colour; 7 stickiness; 8 boiled millet f.; 9 grain f.; 10 sweet f.; 11 salty f.; 12 bitter f.; 13 storage f.; 14 other f.; 15 overall quality.
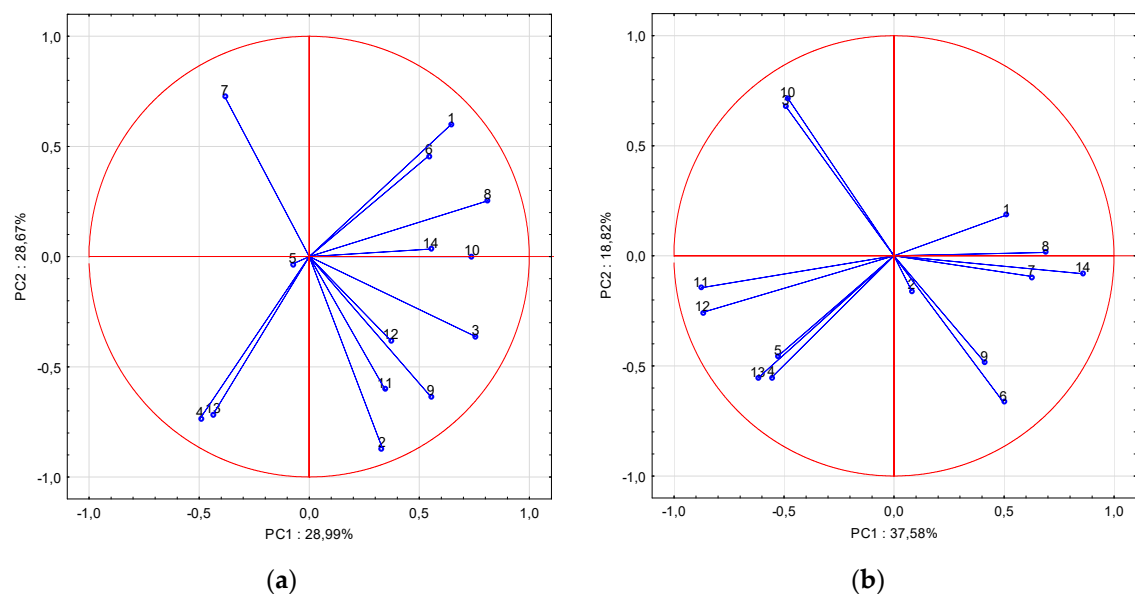
Figure 2. Principal component analysis graphs of the sensory evaluation of the tomato concentrate on (**a**) the DMD and (**b**) after 3 months of storage past the DMD; o: odour; f: flavour; 1 tomato o.; 2 sweet o.; 3 sour o.; 4 other o.; 5 colour; 6 smoothness; 7 thickness; 8 tomato f.; 9 sweet f.; 10 sour f.; 11 tart f.; 12 acetic f.; 13 other f.; 14 overall quality.

The six PCs which explain the variability of the beans in tomato sauce by 83.1% and four PCs which explain the 82.1% initial variability of the stored product were determined.

The overall sensory quality of this food product (vector 15) was strongly correlated with tomato odour and flavour (vectors 1 and 9), and beans odour (vector 2). An undesirable influence on the overall quality was observed for storage and other odours (vectors 4 and 5), and salty flavour (vector 12). For the four other factors, the greatest correlation was observed for the following sensory features: bean and storage flavour (factors 3 and 4), thickness (factor 5) and sweet odour (factor 6) (Figure 3a). In the stored product, a positive correlation was continued in relation to tomato odour and flavour

(vectors 1 and 9) as well as bean odour (vector 2). In addition, storage odour and flavour had an adverse effect on the overall quality of the stored product (vectors 4 and 13) (Figure 3b).

(**a**)   (**b**)
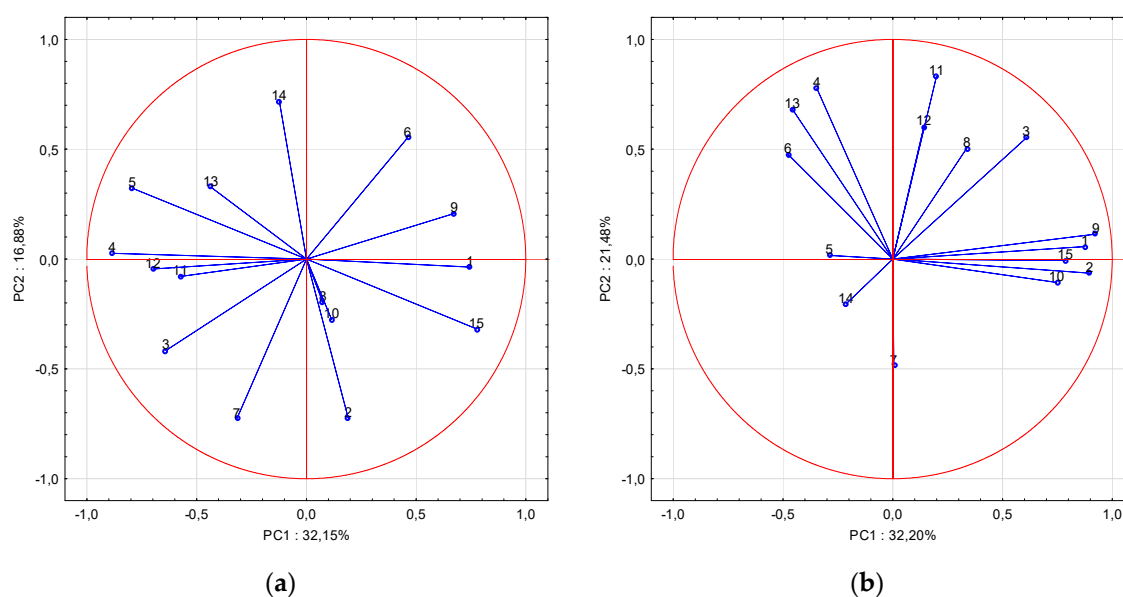
Figure 3. Principal component analysis graphs of the sensory evaluation of the beans in tomato sauce on (**a**) the DMD and (**b**) after 6 months of storage past the DMD; o: odour; f: flavour; 1 tomato o.; 2 bean o.; 3 sweet o.; 4 storage o.; 5 other o.; 6 colour 7 hardness 8 thickness 9 tomato f.; 10 bean f.; 11 sweet f.; 12 salty f.; 13 storage f.; 14 other f.; 15 overall quality.

Regarding the canned tuna, the four PCs which explain the variability of the product by 85.9% and four PCs which explain the 87.4% initial variability of the stored product were determined.

In the case of the canned tuna, the vector direction of metallic odour and flavour (vectors 2 and 12) and fish flavour (vector 9) vs. overall quality (vector 15) allows the conclusion that they were positively correlated with the latter, while rancid and other odours (vectors 3–4) as well as irritating and other flavours (vectors 11 and 14) had a negative impact on the overall quality on the DMD (Figure 4a).

After 6 months of storage, a favourable correlation was maintained between the overall quality and fish odour and flavour (vectors 1 and 9). What is interesting, in relation to metallic odour and flavour (vector 2 and 12), is that this time they were decidedly negatively correlated with overall quality. For the two other factors, the correlation was observed for other flavours (factor 3) and fragmentation (factor 4) (Figure 4b).

In relation to the canned pate, the five PCs which explain the variability of product by 86.5% and five PCs which explain the 87.6% initial variability of the stored product were determined.

The overall sensory quality of the canned pate (vector 15) was strongly correlated with thickness, smoothness and pate flavour (vectors 7–9). An undesirable influence on the overall quality was observed for storage and other odours (vectors 4 and 5), and storage flavour (vector 8). For the three other factors, the greatest correlation was observed for chicken and storage flavours (factor 3 and 4), and colour (factor 5) (Figure 5a). In the stored product, a positive correlation was related to pate odour (vector 1) and smoothness (vector 8). Additionally, odour and flavour had an adverse effect on the overall quality of the stored product (vectors 4 and 13). For the three other factors, the greatest correlation was observed for pate and other flavours (factor 3 and 4), and colour (factor 5) (Figure 5b).
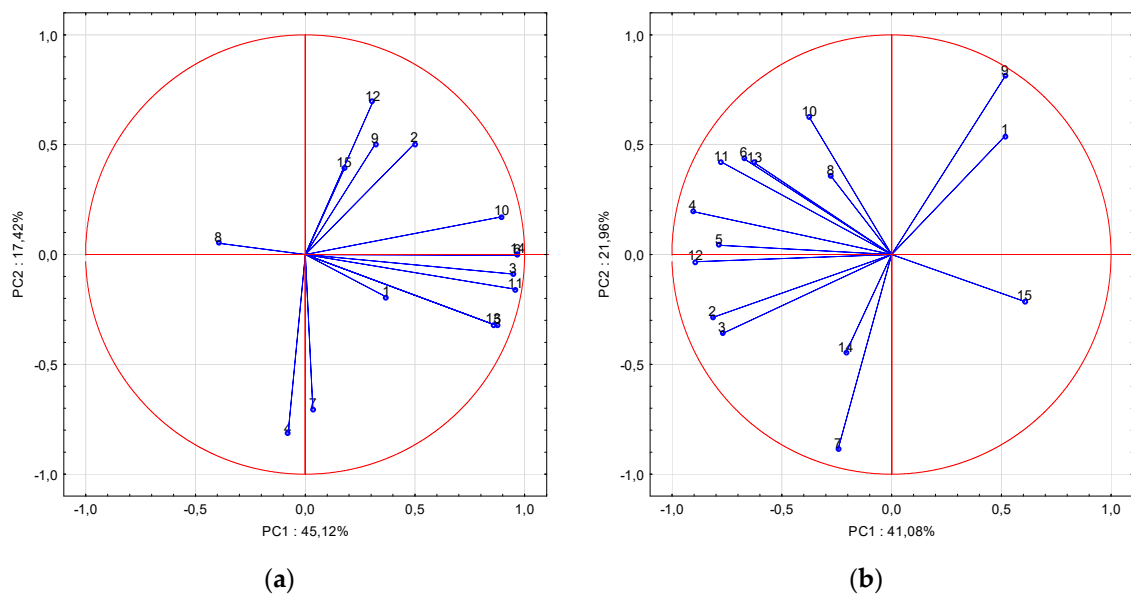
Figure 4. Principal component analysis graphs of the sensory evaluation of the canned tuna on (**a**) the DMD and (**b**) after 6 months of storage past the DMD; o: odour; f: flavour; 1 fish o.; 2 metallic o.; 3 rancid o.; 4 fatty o.; 5 sour o.; 6 other o.; 7 colour 8 fragmentation 9 fish f.; 10 bitter f.; 11 irritating f.; 12 metallic f.; 13 sour f.; 14 other f.; 15 overall quality.
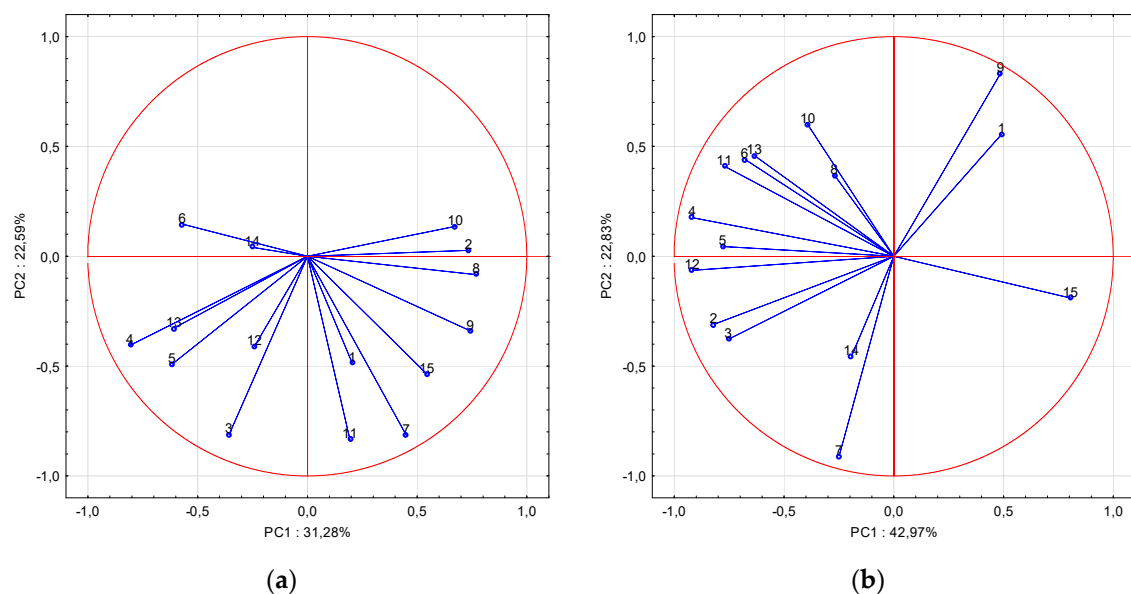
Figure 5. Principal component analysis graphs of the sensory evaluation of the canned pate on (**a**) the DMD and (**b**) after 6 months of storage past the DMD; o: odour; f: flavour; 1 pate o.; 2 chicken o.; 3 pepper o.; 4 storage o.; 5 other o.; 6 colour 7 thickness 8 smoothness 9 pate f.; 10 chicken f.; 11 pepper f.; 12 salty f.; 13 storage f.; 14 other f.; 15 overall quality.

Concerning the sweet cream, the four PCs which explain the variability of product by 85.4% and three PCs which explain the 87% initial variability of the stored product were determined.

On the DMD, only thickness (vectors 8) was positively associated with the overall quality (vector 15). A negative correlation was detected for irritating odour (vector 4) and other flavours (vector 14). For the two other factors, the greatest correlation was observed for sterilisation odour (factor 3) and sour flavour (factor 4). After 6 months of storage, milk and sweet odour (vectors 1–2), and thickness (vector 8) were positively correlated with the overall quality. However, flavours such as

irritating and sterilisation (vectors 11–12) were unfavourable. For the third factor, a correlation was observed for other odours (factor 3) (Figure 6).

(**a**)   (**b**)
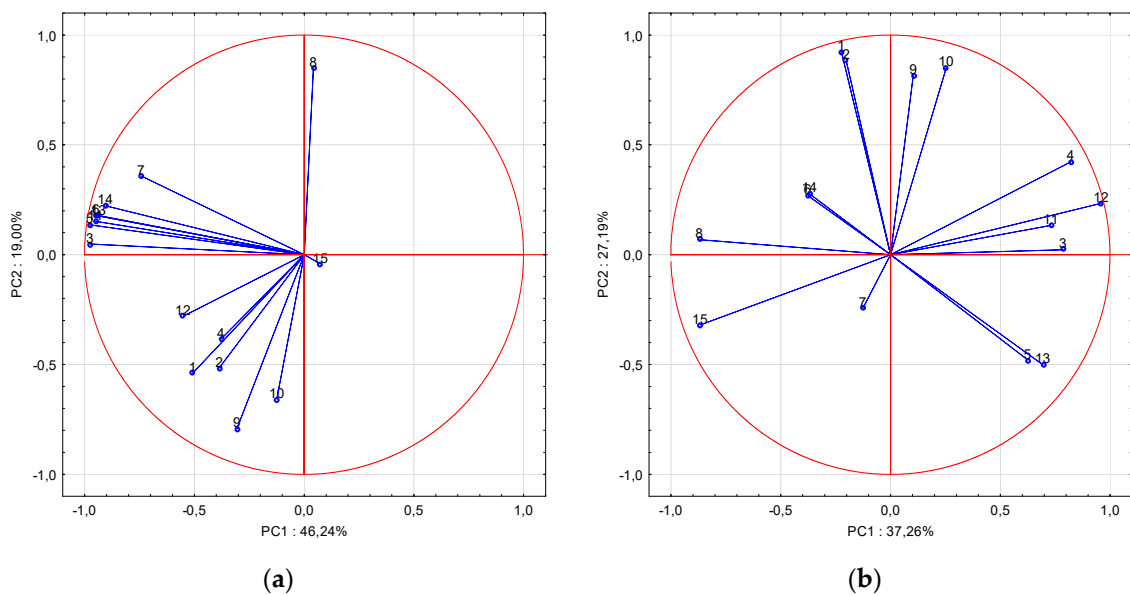
Figure 6. Principal component analysis graphs of the sensory evaluation of the sweet cream on (**a**) the DMD and (**b**) after 6 months of storage past the DMD; o: odour; f: flavour; 1 milk o.; 2 sweet o.; 3 irritating o.; 4 sterilization o.; 5 sour o.; 6 other o.; 7 stickiness 8 thickness 9 milk f.; 10 sweet f.; 11 irritating f.; 12 sterilization f.; 13 sour f.; 14 other f.; 15 overall quality.

3.2.2. Texture Analysis, Viscosity and Colour Determination (L*a*b parameters)

The tested millets were characterised by the parameters specific for this type of product and did not change during the 3-month storage after the minimum durability date. The values of the colour parameter *L* were in the range of 75.22–75.52. The values of the other colour components *a** and *b** were in the range of +2.38–+2.48 and +32.49–+32.78, respectively. In the case of the *a** component, these values indicate the share of red, and in the case of the *b** component, indicate the share of yellow (Table 4). The millet's hardness was in the range of 0.06–0.11 N (Table 5). No significant differences in the components of colour parameters and texture were observed during the storage test ($p > 0.05$).

In the samples of the tomato concentrate, the values of the colour parameter *L* were observed in the range of 27.17–29.46. The values of the colour components *a** and *b** were in the range from +24.85 to +25.91 and from +3.45 to +4.00, respectively. In the case of the *a** component, these values indicate the amount of red colour, but in the case of the *b** component, indicate the yellow colour (Table 4). The flow limit for the tomato concentrate during storage was observed in the range of 437.41–446.79 N/m^2 (Table 5) and was not changed significantly from a statistical point of view ($p > 0.05$).

The values of the colour components for the beans in tomato sauce were as follows. The *L* parameter values were in the range of 52.71–53.02. The values of parameter *a** were in the range of +14.14–+14.59, which indicates the share of red, while values of parameter *b** were in the range of +28.25–+28.92, which indicates the share of yellow (Table 4). The hardness of the beans in tomato sauce during the storage test was in the range of 32.56–32.79 N, and the pH value was observed in the range of 5.12–5.13 (Table 5). All marked parameters did not significantly change during the 6-month storage period ($p > 0.05$).

The marked texture parameter (hardness) of the canned tuna was in the range of 6.64–6.70 N (Table 5). The tested parameters did not change during storage and met the requirements of Codex Alimentarius [30]. The colour parameters also did not change during storage ($p > 0.05$). The values of the parameter *L*, which characterises brightness, were in the range of 58.31–59.20, the values of the parameter *a** were in the range of +7.38–+7.49 (which indicates a greater proportion of red), while the parameter *b** was observed in range of +12.53–+12.70 (which indicates a greater proportion of yellow) (Table 4).

The component values of the colour parameter of the tested canned pate were in the following ranges: parameter *L*; 65.41–65.58, parameter *a**; +7.85–+8.44, indicating a higher value of red colour and parameter *b**; +12.64–+12.76, indicating a higher value of yellow colour (Table 4). Apart from basic raw materials, the colour of sterilised pates can be significantly influenced by the use of meat additives, spices, different amounts of mechanically recovered meat, the use of curing substances or colour stabilisers. No significant differences were observed in the components of the pate's colour parameters during storage ($p > 0.05$). Similar results were obtained in the research done by Tyburcy et al. [31]. The values of the texture parameter of hardness were in the range of 18.22–18.32 N during storage and also did not change significantly.

For the sweet cream, the viscosity was in the range of 60.09–64.23 mPa (Table 5). In the case of the colour, the values of parameter *L*, which indicates brightness, were in the range of 91.24–91.48, the values of parameter *a** were negative and were in the range from −2.87 to −2.94, which proves the share of a green colour. However, the values of the parameter *b** were in the range of +10.58–+10.71, which indicates the share of yellow. All marked parameters did not change significantly during the 6-month storage period ($p > 0.05$).

Table 4. The changes of the *L*, *a* and *b* value of tested product after 6 months of exceeding the DMD.

Product	Colour Value	Time [Month]			
		0	1	3	6
Millet	L	75.52 ± 0.02 [A]	75.22 ± 0.02 [A]	75.31 ± 0.02 [A]	75.28 ± 0.02 [A]
	a	2.48 ± 0.26 [A]	2.38 ± 0.07 [A]	2.43 ± 0.16 [A]	2.44 ± 0.10 [A]
	b	32.57 ± 0.89 [A]	32.70 ± 0.53 [A]	32.49 ± 0.39 [A]	32.50 ± 0.28 [A]
Tomato concentrate	L	29.46 ± 0.02 [A]	27.17 ± 0.02 [A]	28.12 ± 0.04 [A]	28.00 ± 0.03 [A]
	a	24.85 ± 1.93 [A]	25.54 ± 1.25 [A]	25.82 ± 1.30 [A]	25.91 ± 1.25 [A]
	b	3.45 ± 0.58 [A]	3.49 ± 0.65 [A]	3.96 ± 0.30 [A]	4.00 ± 0.30 [A]
Beans in tomato sauce	L	53.02 ± 0.02 [A]	52.77 ± 0.03 [A]	52.71 ± 0.02 [A]	52.77 ± 0.01 [A]
	a	14.14 ± 1.25 [A]	14.29 ± 0.63 [A]	14.59 ± 0.46 [A]	14.37 ± 0.54 [A]
	b	28.75 ± 1.79 [A]	28.25 ± 0.88 [A]	28.92 ± 1.53 [A]	28.59 ± 1.50 [A]
Canned tuna	L	59.20 ± 0.02 [A]	58.88 ± 0.02 [A]	58.31 ± 0.02 [A]	58.94 ± 0.02 [A]
	a	7.38 ± 0.45 [A]	7.40 ± 0.44 [A]	7.40 ± 0.45 [A]	7.49 ± 0.18 [A]
	b	12.70 ± 0.87 [A]	12.53 ± 0.16 [A]	12.56 ± 0.16 [A]	12.57 ± 0.15 [A]
Canned pate	L	65.41 ± 0.07 [A]	65.43 ± 0.06 [A]	65.58 ± 0.05 [A]	65.57 ± 0.02 [A]
	a	7.85 ± 2.18 [A]	7.86 ± 2.18 [A]	8.44 ± 0.25 [A]	8.33 ± 0.24 [A]
	b	12.76 ± 0.21 [A]	12.64 ± 0.22 [A]	12.65 ± 0.20 [A]	12.67 ± 0.22 [A]
Sweet cream	L	91.24 ± 0.61 [A]	91.24 ± 0.03 [A]	91.39 ± 0.04 [A]	91.48 ± 0.03 [A]
	a	−2.94 ± 0.13 [A]	−2.94 ± 0.13 [A]	−2.87 ± 0.12 [A]	−2.93 ± 0.04 [A]
	b	10.71 ± 0.51 [A]	10.71 ± 0.51 [A]	10.58 ± 0.39 [A]	10.68 ± 0.29 [A]

Values denoted by different capital letter in superscripts in the same row differ significantly during storage of each product ($p < 0.05$); (n = 5).

Table 5. The changes of the viscosity, flow limit and hardness value of the tested products after 6 months of exceeding the DMD.

Product	Time (month)			
	0	1	3	6
	Viscosity (mPa)			
Sweet Cream	64.23 ± 0.76 [A]	64.16 ± 0.70 [A]	60.67 ± 0.78 [B]	60.09 ± 0.81 [B]
	Flow limit (N/m²)			
Tomato concentrate	446.79 ± 19.80 [A]	442.31 ± 24.86 [A]	444.89 ± 11.39 [A]	437.41 ± 6.69 [A]
	Hardness (N)			
Millet	0.98 ± 0.11 [A]	1.00 ± 0.06 [A]	0.99 ± 0.07 [A]	0.99 ± 0.06 [A]
Beans in tomato sauce	32.79 ± 0.49 [A]	32.56 ± 0.26 [A]	32.56 ± 0.18 [A]	32.72 ± 0.30 [A]
Canned tuna	6.70 ± 0.25 [A]	6.65 ± 0.14 [A]	6.64 ± 0.10 [A]	6.66 ± 0.10 [A]
Canned pate	18.22 ± 0.61 [A]	18.26 ± 0.29 [A]	18.26 ± 0.18 [A]	18.32 ± 0.06 [A]

Values denoted by different capital letter in superscripts in the same row differ significantly during storage of each product ($p < 0.05$); viscosity (n = 3); flow limit (n = 3); hardness (n = 5).

4. Discussion

Food quality embraces both sensory attributes that are readily perceived by the human senses and hidden attributes, such as safety and nutrition, that require sophisticated instrumentation to measure. Quality is thus a human construct for a product comprising many desired properties and characteristics. Quality produce encompasses sensory properties (appearance, texture, flavour and odour), nutritive values, chemical constituents, mechanical properties, functional properties and defects [32]. In our study, we evaluated factors related to safety and sensory attractiveness due to their leading role in ensuring people's health and well-being.

The most important aspect of food quality is its safety. Pathogenic bacteria could be present in food products and cause illnesses and sometimes death in infected people. Salmonellosis remains the second most commonly reported gastrointestinal infection in humans after campylobacteriosis and is an important cause of food-borne outbreaks in European countries [33]. The prevalence of *Salmonella*-positive samples was reported mostly for egg and egg products, poultry meat and minced meat, as well as for dairy and fruit, vegetables and ready-to-eat products [33]. A statistically significant increasing trend of confirmed listeriosis cases in European countries has been observed in 2009–2018. The case fatality was high (15.6%), which makes listeriosis one of the most serious food-borne diseases under EU surveillance [33]. This was the reason for including *Salmonella* and *Listeria monocytogenes* assays in the evaluation of the tested products. The examined foodstuffs were free from the above-mentioned pathogen on the DMD and after 6 months of storage (Table 2). Similar results were obtained in products such as milk, pasta, mayonnaise and jam [34]. These results demonstrate an adequate preservation technique and product protection against environmental influences, even within 6 months from the DMD.

However, a small number of other microorganisms were detected. The microbial quality of the millet was similar to described in the literature. The millet flakes tested by Takhellambam et al. [35] contained 2.62 log cfu/g TVC and 3.92 cfu/g TYMC as well as a number of *E. coli*, approximately 1.5 cfu/g. After 6 months of storage, the highest number of microorganisms was found in the millet up to approximately 4.36 log cfu/g TVC (Table 2). In the view of the following thermal processing, the recorded microorganism populations can be accepted.

The tested tomato concentrate was produced in good hygienic conditions because the number of bacteria from the *Enterobacteriaceae* family was low (1.85 log cfu/g) and declined below the detection limit after the tested storage time. The total viable count, as well as total yeasts and moulds count, did not reach 3 log cfu/g. However, the product had an a_w around 1.00 but a low pH around 4.2, which ensured the safety of the product (Table 3). Other studies indicated that the microbiological quality of the tomato concentrate was decreased during storage [36,37].

The microbiological quality of the tested beans in tomato sauce was very good. Even after 6 months past the DMD, the number of microorganisms was close or below the detection limit (Table 2). Although the product had an a_w around 1.00 and pH of approximately 5.1 (Table 3), the preservation method and packaging proved to be effective.

The tested canned tuna contained bacteria up to 2.72 log cfu/g after 6 months of exceeding the DMD but the TYMC was below the detection limit (Table 2). Casalinuovo et al. [38] found 2.8 log cfu/g of bacteria from the *Enterobacteriaceae* family in one product (among 15 tested). The same research samples were incubated for 15 days at 35 °C and TVC values between 10 and 10^6 cfu/g were found. These results indicate that a small number of microorganisms in the canned tuna were present, which in the appropriate environmental conditions (high temperature) can begin to multiply.

The canned pate was a foodstuff that contained the smallest number of tested microorganisms, proving the efficiency of the preservation method used for this type of product. The tested sweet cream contained a low number of microorganisms which was below the detection threshold 6 months after exceeding the DMD (Table 2).

The minimum value of water activity necessary for bacterial growth is 0.90, for most yeasts 0.80, and for most moulds 0.70. It is widely accepted that microorganisms cannot grow in foods with

an a_w < 0.6 [39]. In products with a high-water activity, the thermal methods of food preservation definitely increase their durability [39]. Foodstuffs preserved by drying, for example millet, are liable to absorb moisture from the air. Increases in the value of the water activity, which is close to 0.6 in millet after 6 months from the DMD, indicate an increased risk of developing microorganisms in this product (Table 3). Other products (tomato concentrate, beans in tomato sauce, canned tuna, pate and sweet cream) have an a_w close to 1.00, so they were susceptible to microbiological deterioration. However, they were thermally preserved and hermetically sealed, which is why the risk of microbial development is negligible (Table 3).

Regarding changes in the sensory characteristics of the millet, they suggested a decrease in its attractiveness. The quantitative descriptive analysis revealed an increase in the intensity of other odours (described as rancid and storage), and grain and storage flavour, which could be classified as off-odours. On the basis of the principal component analysis, attention should be paid to characteristics like boiled millet odour and flavour, which were positively correlated with the overall quality. On the other hand, storage flavour had a negative influence on the overall quality.

The quality criteria for the tomato concentrate set out in the Codex Alimentarius standard are, first and foremost, an appropriate flavour and odour, a red colour, a homogeneous texture characteristic for the product and a pH value below 4.6 [30]. According to the PC analysis, unfavourable factors included storage odour and flavour, but attention must be paid to thickness and sweet odour (Figure 2). However, a positive influence on the overall quality was indicated in the case of tomato and sweet odour. However, a detrimental influence on the overall quality was observed in relation to other odours as well as tart and acetic flavour. It can be stated that the sensory features of the tested tomato concentrate significantly changed during storage after exceeding the DMD. Subsequent to the 6 months of storage, deterioration of the product was evident, as a result of which the flavour and consistency were not evaluated. The more intense the other odours (defined as vinegar, wine or mouldy) indicated the lower quality of the product. Therefore, the studied tomato concentrate was fit for consumption at almost 3 months after the DMD (Figure A3). Safdar et al. [40] studied pasteurized tomato concentrate stored for 240 days under three different temperature conditions: 25, 6 and −10 °C. The authors found that the higher the temperature, the greater the changes of sensory quality were. The results of the studies indicate that the tomato concentrate stored at room temperature may lose its sensory properties during storage time, which may be one of the limitations of extending the shelf life. On the other hand, changing the storage requirements of the product from room temperature to lower values would allow longer maintenance of the sensory quality at the appropriate level. This could give the possibility of extending the date of minimum durability of tomato concentrate.

The biggest changes in the sensory characteristics of the canned tuna concerned the colour and other odour. A noteworthy correlation was revealed during the PC analysis. On the DMD, a metallic odour was positively correlated with the overall quality; one can say that the odour was harmonised with it. While during the following 6-month storage, the same characteristics were perceived negatively (Figure 4a). An increased intensity of sour and other flavours could be the cause of this phenomenon, among others.

Regarding the canned pate, the smallest fluctuations in the intensity of the tested discriminants (by the QDA method) were found in this product. Based on the PC analysis, consistency (smoothness) plays an important role in the perception of harmonising product features, which is expressed as the overall quality (Figures 5b and A5).

On the last day of the DMD, the sweet cream maintained sensory quality. Similarly, this was observed in the research conducted by Karlsson et al. [41], whose results confirmed that refrigerated or ambient storage temperatures were conditions that gave good sensory properties for UHT milk. Only small flavour deviations were found after long-term storage at 4 and 20 °C. Nevertheless, significant changes were observed regarding the sensory characteristics of the sweet cream in the samples that had been stored for 6 months. A substantial increase in stickiness and thickness was noticed, which resulted in a lower harmonisation of the product, i.e., the overall quality was significantly lower than

in previous months of storage (Figure A6). The positive correlation between the overall quality and thickness vectors (Figure 6) could be connected with the expectation that the product should be thick to achieve a good whipping effect, but this remains ambiguous.

It can be stated that the sensory features of the tested samples were highly harmonized because on the date of minimum durability, the overall quality was above 6 c.u. and remained around this value during storage.

As for the instrumental measurements of the tested products, changes had not been large enough to be reflected in the instrumental measurements of the parameters, such as the colour parameters *L*, *a* and *b*, viscosity and flow limit, and hardness was not significantly different during the tested storage times (Tables 4 and 5).

The obtained results and those presented by Zielińska et al. [34] address the need to define rules for handling food whose minimum durability date is near the end or has already passed. One of the proposals may be the storing of food at a low temperature, which slows the growth of microorganisms [42]. Another principle could be the heat treatment of food, in which the microorganisms that are present would be inactivated. However, this principle requires considering the scenarios of how consumers can apply it. It is also necessary to clarify how long after the date of minimum durability the product can be consumed. The presented study indicates approximately 3 months, however this value requires confirmation through additional research.

5. Conclusions

The evaluated foodstuffs were characterised by a good sensory quality and microbiological safety on the last day of minimum durability. This condition was maintained for up to 3 months of storage. However, after 6 months, significant sensory changes were found which disqualified the products, but they were still safe. Zielińska et al. [34] tested other food products (UHT milk, pasta, mayonnaise and jam) and showed that they were safe and free of microbiological contamination on the DMD, as well as after storage under the conditions recommended by the manufacturer. However, similar to the presented study, the length of storage after the DMD introduced changes in the quality characteristics.

The obtained results provide the basis for establishing guidelines that will facilitate the organisation of traders and food banks as well as consumers to make the decision not to throw away food but consume or transfer it for social purposes. Such activities are an important element of sustainable food systems.

However, it should be remembered that the studies presented are of a pilot nature; they concerned only six selected products and cannot be extrapolated to other foodstuffs. Therefore, research should be continued to learn about changes in other types of food after the date of minimum durability. At the same time, health issues and public opinion should be examined in the context of the problem.

Reducing food waste throughout the agri-food chain, as well as sustainable food choices made by consumers, can contribute to more efficient resource management, increase land use efficiency, improve water management, benefit the entire agricultural sector on a global scale and reduce the number of people starving, thus achieving global food security.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Descriptors and the marks of anchors defined in the quantitative descriptive analysis (QDA).

Product	Descriptor [1]	The Marks of Anchors	Product	Descriptor [1]	The Marks of Anchors
Millet	boiled millet o.	none- very strong	Canned tuna	fish o.	none- very strong
	grain o.	none- very strong		metallic o.	none- very strong
	irritating o.	none- very strong		rancid o.	none- very strong
	sweet o.	none- very strong		fatty o.	none- very strong
	other o.	none- very strong		sour o.	none- very strong
	colour	yellow–grey-brown		other o.	none- very strong
	stickiness	low–high		colour	pink–brown
	boiled millet f.	none- very strong		fragmentation	low–high
	grain f.	none- very strong		fish f.	none- very strong
	sweet f.	none- very strong		bitter f.	none- very strong
	salty f.	none- very strong		irritating f.	none- very strong
	bitter f.	none- very strong		metallic f.	none- very strong
	storage f.	none- very strong		sour f.	none- very strong
	other f.	none- very strong		other f.	none- very strong
	overall quality	low–high		overall quality	low–high
Tomato concentrate	tomato o.	none- very strong	Canned pate	pate o.	none- very strong
	sweet o.	none- very strong		chicken o.	none- very strong
	sour o.	none- very strong		pepper o.	none- very strong
	other o.	none- very strong		storage o.	none- very strong
	colour	red–brown		other o.	none- very strong
	smoothness	sandy–smooth		colour	withe–brown
	thickness	thin–thick		thickness	thin–thick
	tomato f.	none- very strong		smoothness	smooth–lumpy
	sweet f.	none- very strong		pate f.	none- very strong
	sour f.	none- very strong		chicken f.	none- very strong
	tart f.	none- very strong		pepper f.	none- very strong
	acetic f.	none- very strong		salty f.	none- very strong
	other f.	none- very strong		storage f.	none- very strong
	overall quality	low–high		other f.	none- very strong
				overall quality	low–high
Beans in tomato sauce	tomato o.	none- very strong	Sweet cream	milk o.	none- very strong
	bean o.	none- very strong		sweet o.	none- very strong
	sweet o.	none- very strong		irritating o.	none- very strong
	storage o.	none- very strong		sterilization o.	none- very strong
	other o.	none- very strong		sour o.	none- very strong
	colour	withe–brown		other o.	none- very strong
	hardness	none- very strong		stickiness	low–high
	thickness	thin–thick		thickness	thin–thick
	tomato f.	none- very strong		milk f.	none- very strong
	bean f.	none- very strong		sweet f.	none- very strong
	sweet f.	none- very strong		irritating f.	none- very strong
	salty f.	none- very strong		sterilization f.	none- very strong
	storage f.	none- very strong		sour f.	none- very strong
	other f.	none- very strong		other f.	none- very strong
	overall quality	low–high		overall quality	low–high

[1] o.: odour; f.: flavour.
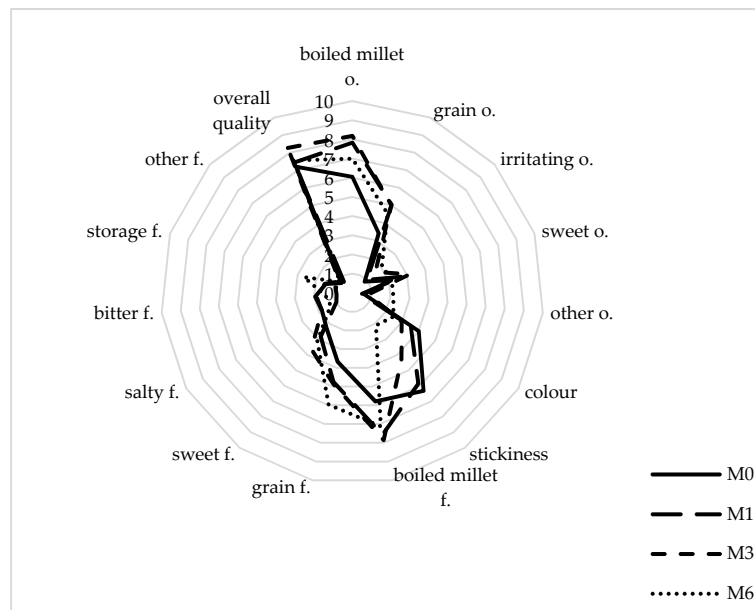
Figure A1. Sensory evaluation of the millet (M) during storage (n = 16); symbol of the product and 0: time 0 (the DMD); 1: after 1 month from the DMD; 3: after 3 months from the DMD; 6: after 6 months from the DMD; o: odour; f: flavour; 1 boiled millet o.; 2 grain o.; 3 irritating o.; 4 sweet o.; 5 other o.; 6 colour; 7 stickiness; 8 boiled millet f.; 9 grain f.; 10 sweet f.; 11 salty f.; 12 bitter f.; 13 storage f.; 14 other f.; 15 overall quality.
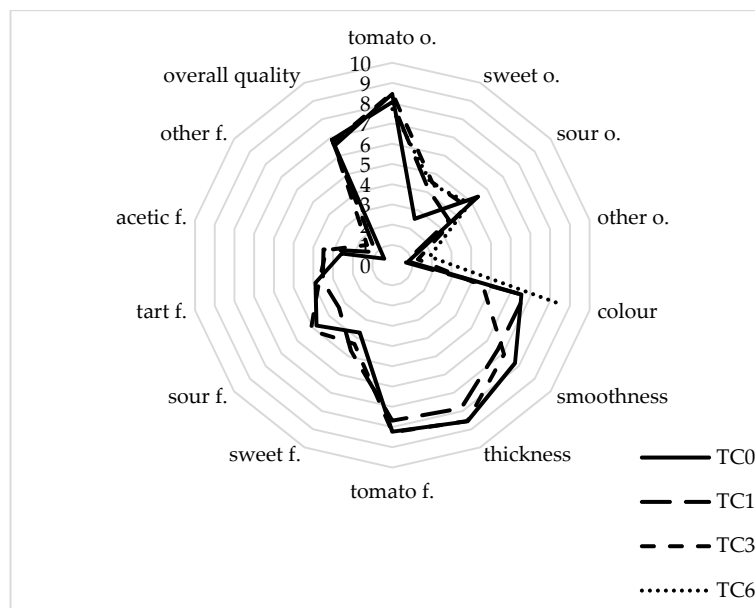
Figure A2. Sensory evaluation of the tomato concentrate (TC) during storage (n = 16); symbol of the product and 0: time 0 (the DMD); 1: after 1 month from the DMD; 3: after 3 months from the DMD; 6: after 6 months from the DMD; o: odour; f: flavour; 1 tomato o.; 2 sweet o.; 3 sour o.; 4 other o.; 5 colour; 6 smoothness; 7 thickness; 8 tomato f.; 9 sweet f.; 10 sour f.; 11 tart f.; 12 acetic f.; 13 other f.; 14 overall quality.
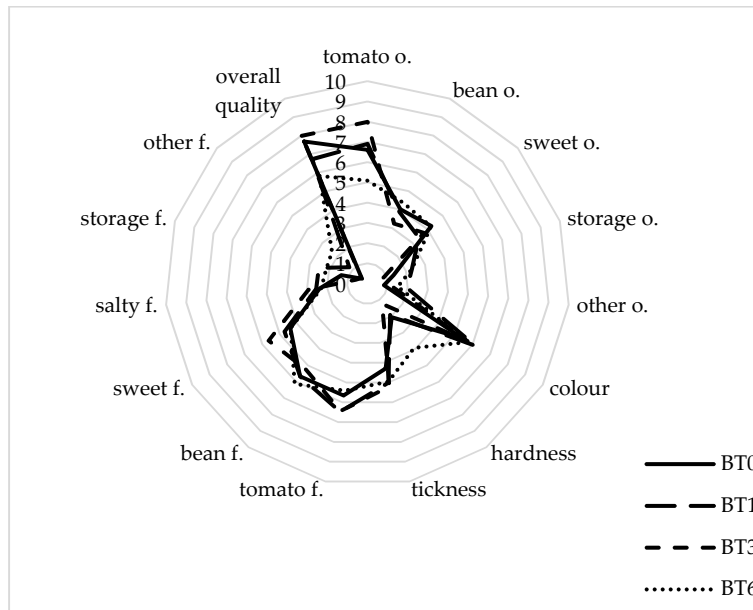
Figure A3. Sensory evaluation of the beans in tomato sauce (BT) during storage (n = 16); symbol of the product and 0: time 0 (the DMD); 1: after 1 month from the DMD; 3: after 3 months from the DMD; 6: after 6 months from the DMD; o: odour; f: flavour; 1 tomato o.; 2 bean o.; 3 sweet o.; 4 storage o.; 5 other o.; 6 colour 7 hardness 8 thickness 9 tomato f.; 10 bean f.; 11 sweet f.; 12 salty f.; 13 storage f.; 14 other f.; 15 overall quality.
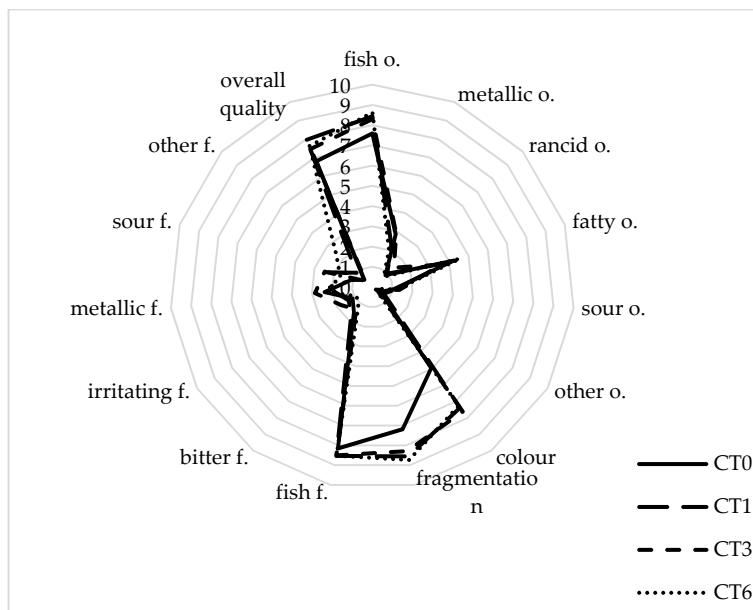
Figure A4. Sensory evaluation of the canned tuna (CT) during storage (n = 16); symbol of the product and 0: time 0 (the DMD); 1: after 1 month from the DMD; 3: after 3 months from the DMD; 6: after 6 months from the DMD; o: odour; f: flavour; 1 fish o.; 2 metallic o.; 3 rancid o.; 4 fatty o.; 5 sour o.; 6 other o.; 7 colour 8 fragmentation 9 fish f.; 10 bitter f.; 11 irritating f.; 12 metallic f.; 13 sour f.; 14 other f.; 15 overall quality.
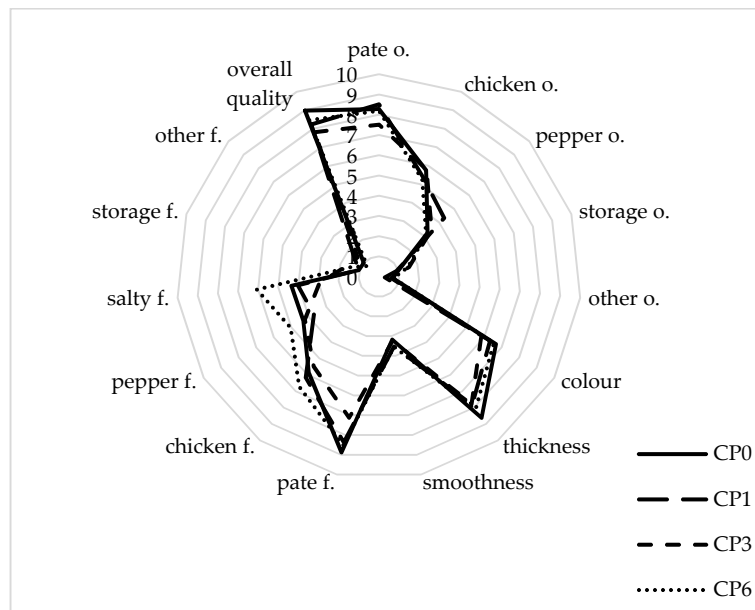
Figure A5. Sensory evaluation of the canned pate (CP) during storage (n = 16); symbol of the product and 0: time 0 (the DMD); 1: after 1 month from the DMD; 3: after 3 months from the DMD; 6: after 6 months from the DMD; o: odour; f: flavour; 1 pate o.; 2 chicken o.; 3 pepper o.; 4 storage o.; 5 other o.; 6 colour 7 thickness 8 smoothness 9 pate f.; 10 chicken f.; 11 pepper f.; 12 salty f.; 13 storage f.; 14 other f.; 15 overall quality..
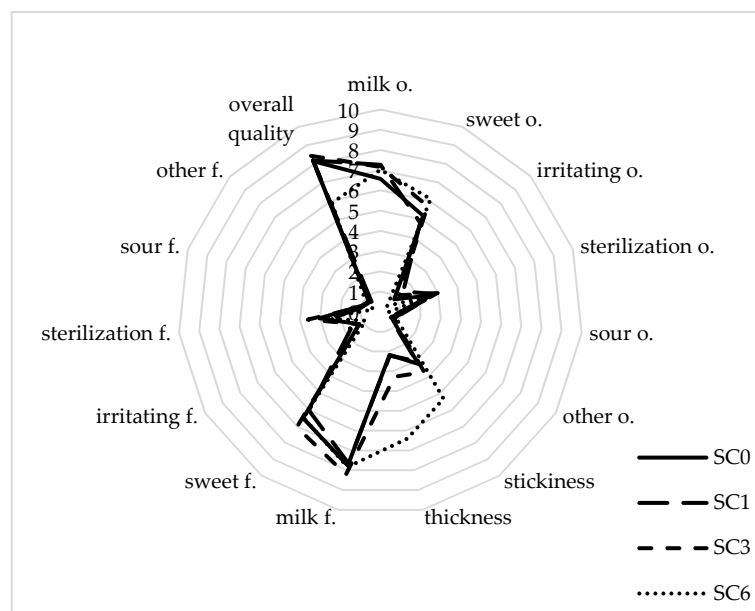
Figure A6. Sensory evaluation of the sweet cream (SC) during storage (n = 16); symbol of the product and 0: time 0 (the DMD); 1: after 1 month from the DMD; 3: after 3 months from the DMD; 6: after 6 months from the DMD; o: odour; f: flavour; 1 milk o.; 2 sweet o.; 3 irritating o.; 4 sterilization o.; 5 sour o.; 6 other o.; 7 stickiness 8 thickness 9 milk f.; 10 sweet f.; 11 irritating f.; 12 sterilization f.; 13 sour f.; 14 other f.; 15 overall quality.

References

1. Lehotay, S.J. Food safety analysis. *Anal. Bioanal. Chem.* **2018**, *410*, 5329–5330. [CrossRef] [PubMed]
2. FAO Food Safety; Main Topics. Available online: http://www.fao.org/food-safety/en/ (accessed on 25 January 2020).
3. Richter, B.; Bokelmann, W. Approaches of the German food industry for addressing the issue of food losses. *Waste Manag.* **2016**, *48*, 423–429. [CrossRef] [PubMed]
4. Gustavsson, J.; Cederberg, C.; Sonesson, U.; van Otterdijk, R.; Meybeck, A. *Global Food Losses and Food Waste: Extent, Causes and Prevention*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2011; ISBN 978-92-5-107205-9.
5. Hall, K.D.; Guo, J.; Dore, M.; Chow, C.C. The Progressive Increase of Food Waste in America and Its Environmental Impact. *PLoS ONE* **2009**, *4*, e7940. [CrossRef]
6. Vijayaraghavan, M.; Jacobs, E.A.; Seligman, H.; Fernandez, A. The Association between Housing Instability, Food Insecurity, and Diabetes Self-Efficacy in Low-Income Adults. *J. Health Care Poor Underserved* **2011**, *22*, 1279–1291. [CrossRef]
7. FAO. *Methods for Estimating Comparable Prevalence Rates of Food Insecurity Experienced by Adults Throughout the World*; Food and Agriculture Organization of the United Nations: Rome, Italy, 2016.
8. Jones, A.D. Food Insecurity and Mental Health Status: A Global Analysis of 149 Countries. *Am. J. Prev. Med.* **2017**, *53*, 264–273. [CrossRef] [PubMed]
9. European Economic and Social Committee Food Donations—Help the Poor and Avoid Food Waste. Available online: https://ec.europa.eu/commission/presscorner/detail/en/CES_14_47 (accessed on 3 February 2020).
10. Global Food Security Index a Report from the Economist Intelligence. Available online: http://foodsecurityindex.eiu.com/ (accessed on 3 February 2020).
11. Mousa, T.Y.; Freeland-Graves, J.H. Organizations of food redistribution and rescue. *Public Health* **2017**, *152*, 117–122. [CrossRef]
12. Mena, C.; Adenso-Diaz, B.; Yurt, O. The causes of food waste in the supplier–retailer interface: Evidences from the UK and Spain. *Resour. Conserv. Recycl.* **2011**, *6*, 648–658. [CrossRef]
13. Garrone, P.; Melacini, M.; Perego, A. Opening the black box of food waste reduction. *Food Policy* **2014**, *46*, 129–139. [CrossRef]
14. Bilska, B.; Piecek, M.; Kołożyn-Krajewska, D. A Multifaceted Evaluation of Food Waste in a Polish Supermarket—Case Study. *Sustainability* **2018**, *10*, 3175. [CrossRef]
15. Bilska, B.; Kołożyn-Krajewska, D. Risk Management of Dairy Product Losses as a Tool to Improve the Environment and Food Rescue. *Foods* **2019**, *8*, 481. [CrossRef]
16. *Regulation (EU) No 1169/2011 Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the Provision of Food Information to Consumers, Amending Regulations (EC) No 1924/2006 and (EC) No 1925/2006 of the European Parliament and of the Council, and Repealing Commission Directive 87/250/EEC, Council Directive 90/496/EEC, Commission Directive 1999/10/EC, Directive 2000/13/EC of the European Parliament and of the Council, Commission Directives 2002/67/EC and 2008/5/EC and Commission Regulation (EC) No 608/2004 2011*; European Parliament: Brussels, Belgium.
17. Toma, L.; Costa Font, M.; Thompson, B. Impact of consumers' understanding of date labelling on food waste behaviour. *Oper. Res. Int. J.* **2017**, 1–18. [CrossRef]
18. Kasza, G.; Szabó-Bódi, B.; Lakner, Z.; Izsó, T. Balancing the desire to decrease food waste with requirements of food safety. *Trends Food Sci. Technol.* **2019**, *84*, 74–76. [CrossRef]
19. ISO 4833-1:2013. *Microbiology of the Food Chain—Horizontal Method for the Enumeration of Microorganisms—Part 1: Colony Count at 30 °C by the Pour Plate Technique*; ISO: Geneva, Switzerland, 2013.
20. PN-ISO 21528-2:2017. *Microbiology of Food and Feeding Stuffs—Horizontal Method for the Detection and Enumeration of Enterobacteriaceae—Part 2: Colony Count Method*; ISO: Geneva, Switzerland, 2017.
21. ISO 21527-1:2008. *Microbiology of Food and Animal Feeding Stuffs—Horizontal Method for the Enumeration of Yeasts and Moulds—Part 1: Colony Count Technique in Products with Water Activity Greater than 0.95*; ISO: Geneva, Switzerland, 2008.
22. ISO 21527-2:2008. *Microbiology of Food and Animal Feeding Stuffs—Horizontal Method for the Enumeration of Yeasts and Moulds—Part 2: Colony Count Technique in Products with Water Activity Less than or Equal to 0.95*; ISO: Geneva, Switzerland, 2008.

23. ISO 6579-1:2017. *Microbiology of the Food Chain—Horizontal Method for the Detection, Enumeration and Serotyping of Salmonella—Part 1: Detection of Salmonella spp*; ISO: Geneva, Switzerland, 2017.

24. ISO 11290-1:2017. *Microbiology of Food and Animal Feeding Stuffs—Horizontal Method for the Detection and Enumeration of Listeria Monocytogenes and Others Listeria spp.—Part 1: Detection Method*; ISO: Geneva, Switzerland, 2017.

25. ISO 18787:2017. *Food Stuffs—Determination of Water Activity*; ISO: Geneva, Switzerland, 2017.

26. ISO 13299:2016. *Sensory Analysis-Methodology-General Guidance for Establishing a Sensory Profile*; ISO: Geneva, Switzerland, 2016.

27. Papadakis, S.E.; Malek, S.A.; Kamdem, R.E.; Yam, K.L. A Versatile and Inexpensive Technique for Measuring Color of Foods. *Food Technol.* **2000**, *54*, 48–51.

28. Berk, Z. Water Activity, Definition, and Determination. In *Food Process Engineering and Technology*, 3rd ed.; Elsevier: Amsterdam, The Netherlands, 2018; p. 11.

29. Sadowska, A.; Świderski, F.; Rakowska, R.; Kostyra, E.; Piotrowska, A. Przydatność metody ilościowej analizy opisowej (QDA) i analizy składowych głównych (PCA) na Przykładzie oceny sensorycznej grillowanych Steków wołowych. *Żywność. Nauka. Technol. Jakość* **2015**, *101*, 99–112.

30. *CXS 70—Codex Standard for Canned Tuna and Bonito*; Food and Agriculture Organization: Quebec City, QC, Canada, 1981.

31. Tyburcy, A.; Kosińska, A.; Cegiełka, A. Characteristics of sterilized liver paté manufactured from different raw materials. *Acta Sci. Pol. Technol. Aliment.* **2005**, *4*, 103–110.

32. Jha, S.N. Food Safety and Quality. In *Rapid Detection of Food Adulterants and Contaminants—Theory and Practice*; Elsevier: Amsterdam, The Netherlands, 2016; p. 21, ISBN 978-0-12-420084-5.

33. The European Union One Health 2018 Zoonoses Report. *Efsa J.* **2019**, *17*, e05926.

34. Zielińska, D.; Bilska, B.; Marciniak-Łukasiak, K.; Łepecka, A.; Trząskowska, M.; Neffe-Skocińska, K.; Tomaszewska, M.; Szydłowska, A.; Kołożyn-Krajewska, D. Consumer Understanding of the Date of Minimum Durability of Food in Association with Quality Evaluation of Food Products After Expiration. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1632. [CrossRef]

35. Takhellambam, R.D.; Chimmad, B.V.; Prkasam, J.N. Ready-to-cook millet flakes based on minor millets for modern consumer. *J. Food Sci. Technol.* **2016**, *53*, 1312–1318. [CrossRef]

36. Basak, S. Shelf Life Extension of Tomato Paste Through Organoleptically Acceptable Concentration of Betel Leaf Essential Oil Under Accelerated Storage Environment. *J. Food Sci.* **2018**, *83*, 1396–1403. [CrossRef]

37. Villari, P.; Costabile, P.; Fasanaro, G.; Sio, F.D.; Laratta, B.; Pirone, G.; Castaldo, D. Quality loss of double concentrated tomato paste: Evolution of the microbial flora and main analytical parameters during storage at different temperatures. *J. Food Process. Preserv.* **1994**, *18*, 369–387. [CrossRef]

38. Casalinuovo, F.; Gazzotti, T.; Rippa, P.; Ciambrone, L.; Musarella, R.; Pratticò, E. Microbiological Stability of Canned Tuna Produced in Italy and in Non-European Countries. *Ital. J. Food Saf.* **2015**, *4*, 4780. [CrossRef] [PubMed]

39. Pałacha, Z.; Makarewicz, M. Aktywność wody wybranych grup produktów spożywczych (Water activity of selected food groups). *Postępy Tech. Przetwórstwa Spożywczego* **2011**, *2*, 24–39.

40. Safdar, M.N.; Mumtaz, A.; Amjad, M.; Siddiqui, N.; Hameed, T. Development and Quality Characteristics Studies of Tomato Paste Stored at Different Temperatures. *Pak. J. Nutr.* **2010**, *9*, 265–268.

41. Karlsson, M.A.; Langton, M.; Innings, F.; Malmgren, B.; Höjer, A.; Wikström, M.; Lundh, Å. Changes in stability and shelf-life of ultra-high temperature treated milk during long term storage at different temperatures. *Heliyon* **2019**, *5*, e02431. [CrossRef]

42. Nedwell, D.B. Effect of low temperature on microbial growth: Lowered affinity for substrates limits growth at low temperature. *FEMS Microbiol. Ecol.* **1999**, *30*, 101–111. [CrossRef]