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QUALITY CHANGES OF LONG-LIFE FOODS DURING THREE-MONTH STORAGE AT DIFFERENT TEMPERATURES

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ABSTRACT

The aim of this study was to describe quality changes of eight long-life foods (instant potato purée with milk, instant goulash soup, canned white-type cheese, pre-baked baguette, szeged goulash meal-ready-to-eat, canned chicken meat, pork pate and canned tuna fish) during three-month storage at 4 different temperatures (-18 °C, 5 °C, 23 °C and 40 °C). These temperatures were chosen to simulate various climatic conditions in which these foods could be used to ensure the boarding during crisis situations and military operations to provide high level of sustainability. Foods were assessed in terms of microbiological (total number of aerobic and/or facultative anaerobic mesophilic microorganisms, number of aerobic and anaerobic spore-forming microorganisms, number of enterobacteria, number of yeasts and/or moulds), chemical (pH-values, dry matter, fat, crude protein, ammonia and thiobarbituric acid reactive substances contents), texture profile (hardness) and sensory (appearance, consistency, firmness, flavour and off-flavour) analyses. Microbiological analyses showed expected results with the exception of szeged goulash, pork pate and tuna fish, which, although being sterilised products, contained some counts of bacteria. The decrease of pH-values and increase of dry matter, ammonia and thiobarbituric acid reactive substances contents were observed during the storage of all foods due to prolonged storage time and/or elevated storage temperature. Furthermore, according to texture profile analysis, hardness of cheese and baguette rose as a result of both storage temperature and time. Finally, the highest storage temperature (40 °C) resulted in a deterioration of sensory quality (especially flavour) of most foods; the exceptions were pate and tuna fish which retained good sensory quality throughout 3-month storage at all temperatures.

Keywords: long-life foods; long-term storage; quality changes; crisis boarding; combat ration

INTRODUCTION

Minimum shelf-life of foods used in combat rations (CR) of several armies is according to requirements of **STANAG 2937 (2015)** minimally 24 months. CR are developed with an aim to meet complete daily nutrition needs of individuals in environments where standard food cannot be supplied by common means (e.g. in natural disasters, war conflicts, etc.). Energy and nutritional values of CR are in accordance with the needs of members of the army during a long-term strenuous physical activity and comply with the requirements for a basic 24-hour food ration in NATO armies. Foods designed primarily for CR can also be used as a part of emergency relief programmes operated by national and regional authorities. In addition, such foods may be utilized during recreational and sports activities when refrigeration facilities are not available. Foods from Czech CR are suitable for temperate climatic zone (guaranteed 24-month shelf life when stored at temperatures from 0 to 25 °C and relative humidity of up to 70%); however, the army could operate also in arctic (up to -20 °C) or tropical (over 30 °C) climate zones. Furthermore, temperatures exceeding temperate climate zone can be expected during crisis boarding. Thus, not only ambient, but also frozen and elevated temperature conditions should be considered during the analysis of quality changes of foods intended for CR and crisis boarding.

Various changes leading to the reduction of nutritive value, the decrease of protein/starch digestibility and the worsening of some nutrient bioavailability (essential amino acids, etc.) could be expected during a 2-year storage of food products. Several reactions are responsible for most degradation of basic nutrients such as proteins, lipids, and carbohydrates, but also some minor food components **(Zasypkin and Lee, 2002)**. Even sterilized or dehydrated food products are not completely stable and their long-term storage is connected with significant physico-chemical development, especially at elevated temperatures **(Gliguem and Birlouez-Aragon, 2005)**. Nutritive deterioration of proteins is mainly due to nonenzymatic Maillard reactions that leads to amino acid losses, reduced digestibility owing to protein cross-linking, colour changes (darkening), texture toughening, and off-flavour development **(Barnett and Kim, 1998; Pizzoferrato et al., 1998; Kristensen et al., 2001)**. The extent of nonenzymatic browning during storage develops as a result of rising amount of reducing sugars, higher storage temperature, and increased origination of oxidized lipids **(Kristensen et al., 2001; Schär and Bosset, 2002; Gaucher et al., 2008)**. The most important amino acid destructive reactions are Strecker degradation giving rise to ammonia, racemization, and oxidative reactions **(Adamiec et al., 2001)**. Furthermore, some amino acids, especially lysine, could undergo reactions resulting in the formation of bonds that are not cleaved by enzymes in human digestive tract and thus, these amino acids are not bio-available **(Ferrer et al., 2000; Torbatinejad et al., 2005)**. Lipids are subjected to lipolysis, autoxidation, and enzymatic oxidation by lipoxygenases. Lipolysis promotes off-flavour development and changes in functional properties of lipids; lipid oxidation causes rancid off-flavour enhancement, colour and texture changes and nutritional quality deterioration **(Nawar, 1998; Kristensen and Skibsted, 1999; Tkáčová et al., 2015)**. Starch retrogradation, that induces crystallization of amylose and amylopectin together with hydrogen bond formation, is the main reason for texture toughening of starch-containing food products **(Gordon and Davis, 1998)**. Reducing sugars (monosaccharides and disaccharides) are involved in Maillard reactions, as was mentioned above.

The shelf-stability of long-life food products could be improved by e.g. vacuum-packaging with high barrier materials, reformulation of the products, innovative preservation technologies, novel packaging materials, and/or antimicrobial additives **(Zasypkin and Lee, 2002)**.

Physical, chemical and nutritive changes in a variety of selected products should be monitored during at least 2 years of storage at different temperatures to ensure that foods retain good nutritive and sensory quality and meet food safety requirements. Similar studies dealing with long-term storage of such wide range of foods at different temperatures are very scarce. Most of the research works on changes in food products are limited to six-month storage period and/or deal only with two storage temperatures. Other data are derived from accelerated storage tests conducted at elevated temperatures during several days or weeks.

This paper is a kick-off work of 24-month storage study; the complete results will be published subsequently. Moreover, further storage experiments with different types of food will be set promptly. The objective of this work was to determine quality changes (microbiological, chemical, textural and sensory) of various foods during 3-month storage at -18, 5, 23 and 40 °C.

MATERIAL AND METHODOLOGY

Eight types of foods were chosen for the storage experiment: (i) instant potato purée with milk (Natura Inc., Czech Republic); (ii) instant goulash soup (Hügli Food Ltd., Czech Republic); (iii) canned white-type cheese (Mlékárna Polná Ltd., Czech Republic), pre-baked baguette (IBIS Backwarenvertriebs BmbH, Germany); (iv) szeged goulash meal-ready-to-eat (Hamé Ltd., Czech Republic); (v) canned chicken meat (Hamé Ltd., Czech Republic); (vi) pork pate (Hamé Ltd., Czech Republic); and (vii) canned tuna fish (Gaston Ltd., Czech Republic; country of origin: Spain). The minimum shelf-life of these foods is 2 years, with the exception of purée and soup (1 year), cheese (4 months) and baguette (3 months), which were selected as the representatives of dehydrated, milk and bakery products with the longest shelf-life. Furthermore, one of the goal of this work was to examine the shelf-life of these foods. Potato purée, goulash soup, baguette and szeged goulash were treated according to the instructions for use (i.e. poured with hot water, baked and heated, respectively) before sensory analysis; other foods did not require any preparation.

Storage experiment with 8 types of food was performed in a freezer (-18 °C), refrigerator (5 °C), storeroom (23 °C) and thermostat (40 °C). Generally, all foods were subjected to microbiological (total number of aerobic and/or facultative anaerobic mesophilic microorganisms, number of aerobic and anaerobic spore-forming microorganisms, number of enterobacteria, number of yeasts and/or moulds), chemical (pH-values, dry matter, fat, crude protein, ammonia and thiobarbituric acid reactive substances contents), texture and sensory analyses at the beginning of the experiment and after 3-month storage at 4 temperatures. Furthermore, food products kept at 40 °C were assessed also after 1-month storage. These exceptions were applied during the experiment: (i) number of enterobacteria was determined only in cheese and baguette, (ii) fat and crude protein contents were considered only at the beginning of the experiment, and (iii) texture profile analysis was applied only in cheese, baguette, chicken meat and pate.

Total number of aerobic and/or facultative anaerobic mesophilic microorganisms was determined according to ISO 4833-1:2013, number of aerobic and anaerobic spore-forming microorganisms according to **Harrigan (1998)**, number of enterobacteria according to ISO 4832:2006 and number of yeasts and/or moulds according to **ISO 6611:2004**.

Values of pH were measured using a pH meter with spear electrode (Eutech Instruments). Dry matter content was provided after evaporating the water content at 103 ±2 °C until constant mass loss was obtained; see sand was used as a soaking agent if necessary. Fat and crude protein contents were evaluated using Soxhlet and Kjeldahl methods, respectively. Ammonia content was estimated by means of Conway method, as was described by **Buňka et al (2004)**. Thiobarbituric acid reactive substances (TBARS) content was utilized to consider the secondary products of lipid oxidation; method characterised in **Kristensen and Skibsted (1999)** was used. Wavelength $\lambda = 450$ nm was used for foods providing yellow products (i.e. potato purée, white-type cheese, baguette and szeged goulash), whereas $\lambda = 538$ nm was used for foods giving rise to red products (i.e. goulash soup, chicken meat, pate and tuna fish). The absorption maxima were obtained from the absorbance spectrum (200 – 800 nm). Results were expressed as absorbance units at particular wavelength per mg of sample; i.e. either as $A450 \cdot mg^{-1}$ or $A538 \cdot mg^{-1}$. All of the basic chemical analyses were performed at least in triplicate.

The texture analysis was carried out by means of Texture Analyser TA.XTPlus (Stable Micro Systems). The samples were subjected to double compression by 80% of the initial sample's height using a 100 mm plate (speed of the probe 1 $mm.s^{-1}$, trigger force of 5 g). The results obtained were recorded as force-displacement/time curves describing the force (N) needed to deform the sample proportionally with time (s). Hardness (maximum force during the first compression cycle; N) was determined according to these curves **(Szczesniak, 2002; Weiserová et al., 2011)**. The measurement was performed at room temperature (21 ±2 °C) and each sample was analysed three times.

Sensory evaluation was accomplished by a sensory panel consisted of 12 selected assessors trained according to the ISO 8586:2012. A seven-point hedonic scale (1 – excellent, 4 – good, 7 – unacceptable) was used for the assessment of appearance, consistency and flavour, whereas a seven-point intensity scale (1 – negligible, 4 – medium, 7 – excessive) was used for the establishment of firmness and off-flavour intensity. Results were presented as medians.

RESULTS AND DISCUSSION

The results of microbiological analysis of examined food products throughout the 3-month storage showed that the highest counts of microorganisms were detected in two dehydrated instant products, i.e. potato purée and goulash soup (up to 10^5 $CFU\cdot g^{-1}$). Cans and the rest of foods contained less microorganisms (maximally 10^4 $CFU\cdot g^{-1}$). The only product containing small amounts of yeast and/or moulds was, as expected, white-type cheese. However, surprising results were obtained in monitored cans stored in thermostat. Whereas chicken meat did not involve any microorganisms, pate and tuna fish comprised some counts of total number of aerobic and/or facultative anaerobic mesophilic microorganisms and, furthermore, szeged goulash also some spore-forming microorganisms (up to 10^2 $CFU\cdot g^{-1}$). These outcomes indicate germinating of spores which were not inactivated in the sterilisation process.

Results of basic chemical analyses are presented in Table 1 and 2. Values of pH obtained are common values for various food products. pH-values of samples did not show expressive alteration during 3-month storage; however, there was a slight decrease of pH observed in most of the foods owing to growing storage temperature (see Table 1). Dry matter of samples ranged from 20.6 (in tuna fish) to 98.4% (in dehydrated samples – purée and soup). There were only minor changes of dry matter content detected in canned food (chicken meat and tuna fish) during the storage. On the other hand, foods packed in different containers with worse barrier characteristics showed increase of dry matter content through 3-month storage; this growth was more significant at higher temperature. The most intensive changes were noticed in white-type cheese – dry matter of cheese stored for 3 months in thermostat raised about 20% compared to the beginning of the experiment (Table 1). Both fat (Table 1) and crude protein (Table 2) contents analysed in all foods were in accordance with nutrition declaration on packaging.

Ammonia is an important product of various reactions occurring during food storage (e.g. Maillard reactions, Strecker degradation of amino acids, and other deamination reactions) whose high amounts can be considered as food spoilage marker **(Friedman, 1996; Efigênia et al., 1997; Pizzoferrato et al., 1998; Adamiec et al., 2001)**. Ammonia content varied from 14.9 to 161.8 $mg\cdot kg^{-1}$. Both higher storage temperature and length of storage provoked elevated concentration of ammonia in all food products. These changes were more distinctive if foods with higher protein content. The most expressive ammonia amount growth was registered in goulash soup; sample stored for 3 months in thermostat showed 4 times higher ammonia concentration compared to the beginning of the storage experiment (Table 2). Increasing ammonia contents due to elevated storage temperature (37 °C) were reported for processed cheese by **Bubelová et al. (2015)**.

The primary lipid oxidation products, peroxides, were found to provide little information about the oxidative process in food. Thus, secondary lipid oxidation products (mainly aldehydes) originating form peroxides at later stages of oxidation process are mostly considered as a marker of lipid oxidation intensity **(Kristensen et al., 2001)**. The amount of the secondary products of lipid oxidation was assessed as TBARS. Whereas yellow pigments are formed when secondary lipid oxidation products originate from peroxides of monounsaturated fatty acids, red pigments come from oxidized polyunsaturated lipids **(Hoyland and Taylor, 1991)**. TBARS contents ranged between 6.7 – 477.6 absorbance units per mg of sample. The rise of TBARS was caused by both storage length and higher storage temperature. The highest TBARS levels were detected in samples stored for three months at 40 °C in the case of all products. The greatest rising was noticed in white-type cheese, baguette and pork pate; thermostat samples of these foods after 3-month storage showed 4 – 5 times higher TBARS amounts compared to the beginning of the experiment (Table 2). An increase in TBARS owing to higher storage temperature (37 °C) of processed cheese was noted by **Kristensen et al. (2001)** and **Kristensen and Skibsted (1999)**.

Results of texture analysis (hardness) are shown in Figure 1. Samples of cheese, unpredictably, hardened very quickly, and, thus, already after 1 month of storage, it was not possible to use 80% compression. Similarly, baguette samples stored for three months in thermostat were not possible to compress by 80%. Therefore 50% compression was employed instead in these samples. Consequently, results obtained with different compressions cannot be compared mutually. Nevertheless, it can be concluded from the available results that both cheese and baguette samples became harder due to both storage length and elevated storage temperature.

On the other hand, chicken meat and pate samples did not alter hardness significantly through the storage. These findings are in good agreement with those for dry matter content (see Table 1). While the dry matter of cheese and baguette increased during the storage, dry matter of chicken meat and pate remained almost constant owing to containers with good barrier efficiency.

Table 1 Results of pH-values, dry matter and fat content during 3-month storage.

Food	Length of storage (months)	Temperature of storage (°C)	pH (-)	Dry matter (%)	Fat content (%)
Potato purée	0	-	6.04 ±0.01	94.81 ±1.09	2.29 ±0.03
	1	40	5.91 ±0.01	95.68 ±1.14	NA
	3	-18	6.00 ±0.00	96.66 ±1.26	NA
		5	5.98 ±0.01	96.52 ±1.18	NA
		23	5.97 ±0.00	96.24 ±1.19	NA
		40	5.90 ±0.00	97.27±1.10	NA
Goulash soup	0	-	5.58 ±0.01	95.51 ±1.18	12.73 ±0.21
	1	40	5.49 ±0.01	95.17 ±1.24	NA
	3	-18	5.77 ±0.01	98.41 ±1.35	NA
		5	5.74 ±0.03	98.40 ±1.29	NA
		23	5.64 ±0.01	98.41 ±1.14	NA
		40	5.39 ±0.01	97.68 ±1.17	NA
Cheese	0	-	5.00 ±0.02	41.04 ±0.91	20.95 ±0.26
	1	40	4.80 ±0.01	55.05 ±0.40	NA
	3	-18	4.69 ±0.01	46.86 ±0.52	NA
		5	4.48 ±0.00	48.17 ±0.24	NA
		23	4.37 ±0.02	55.57 ±0.38	NA
		40	4.30 ±0.00	60.63 ±0.43	NA
Baguette	0	-	5.56 ±0.01	64.57 ±0.53	1.27 ±0.01
	1	40	5.50 ±0.02	70.73 ±0.67	NA
	3	-18	5.73 ±0.04	67.19 ±0.50	NA
		5	5.67 ±0.01	67.16 ±0.47	NA
		23	5.66 ±0.00	67.82 ±0.51	NA
		40	5.51 ±0.01	76.53 ±0.82	NA
Szeged goulash	0	-	4.54 ±0.01	15.82 ±0.39	9.73 ±0.10
	1	40	4.40 ±0.01	17.55 ±0.43	NA
	3	-18	4.67 ±0.02	16.82 ±0.16	NA
		5	4.61 ±0.01	16.07 ±0.26	NA
		23	4.60 ±0.01	17.42 ±0.10	NA
		40	4.59 ±0.01	17.69±0.15	NA
Chicken meat	0	-	6.37 ±0.01	27.09 ±0.30	6.13 ±0.08
	1	40	6.33 ±0.00	27.80 ±0.36	NA
	3	-18	6.72 ±0.01	24.40 ±0.19	NA
		5	6.69 ±0.01	25.82 ±0.34	NA
		23	6.67 ±0.01	26.21 ±0.28	NA
		40	6.68 ±0.02	26.45 ±0.25	NA
Pate	0	-	6.04 ±0.01	43.55 ±0.45	28.14 ±0.37
	1	40	6.05 ±0.00	45.17 ±0.57	NA
	3	-18	6.14 ±0.02	45.16 ±0.41	NA
		5	6.10 ±0.01	45.28 ±0.39	NA
		23	6.08 ±0.00	45.27 ±0.53	NA
		40	6.09 ±0.01	46.68 ±0.37	NA
Tuna fish	0	-	5.72 ±0.01	21.29 ±0.26	1.80 ±0.02
	1	40	5.53 ±0.02	21.16 ±0.22	NA
	3	-18	6.00 ±0.01	21.42 ±0.19	NA
		5	6.00 ±0.01	21.65 ±0.23	NA
		23	5.97 ±0.00	20.89 ±0.37	NA
		40	5.95 ±0.01	20.61 ±0.24	NA

Note: * Results are presented as means ± SD. NA – not analysed.

Hardening of cheese as a consequence of dry matter increase could be most likely attributed to the rearranging of protein matrix (e.g. cross-linking of casein network); these modifications were probably more intense at higher storage temperature **(Karami et al., 2009)**. Concerning the baguette, increased hardness reflects the gluten network alteration and starch retrogradation. Hardness enhancing of baguette bread during the 45-day storage was noted by **Rashidi et al. (2016)**. Similarly, **Sha et al. (2007)** observed hardening during the prolonged storage of traditional Chinese steamed bread.

Table 2 Results of crude protein, ammonia and TBARS contents during 3-month storage.

Food	Length of storage (months)	Temperature of storage (°C)	Crude protein (%)	Ammonia (mg·kg^{-1})	TBARS (A_{450}·mg^{-1} or A_{538}·mg^{-1})
Potato purée	0	-	8.84 ±0.12	38.08 ±0.74	55.67 ± 1.04
	1	40	NA	49.77 ±0.96	90.40 ±2.56
	3	-18	NA	37.83 ±0.67	60.53 ±1.12
		5	NA	38.69 ±0.80	119.53 ±2.45
		23	NA	39.38 ±0.84	121.20 ±2.17
		40	NA	56.21 ±1.02	129.13 ±2.62
Goulash soup	0	-	12.50 ±0.21	39.92 ±0.87	136.20 ±3.08
	1	40	NA	95.20 ±2.73	157.07 ±3.19
	3	-18	NA	101.43±2.91	143.47 ±3.12
		5	NA	128.20 ±3.04	144.28 ±3.20
		23	NA	152.32 ±3.16	154.80 ±3.29
		40	NA	161.84 ±3.63	306.67 ±5.64
Cheese	0	-	15.78 ±0.30	15.23 ±0.28	7.20 ±0.12
	1	40	NA	43.16 ±0.91	18.47 ±0.41
	3	-18	NA	15.47 ±0.30	23.80 ±0.49
		5	NA	20.31 ±0.43	24.53 ±0.53
		23	NA	38.08 ±0.67	28.13 ±0.58
		40	NA	53.31 ±1.12	35.94 ±0.64
Baguette	0	-	7.39 ±0.09	14.97 ±0.24	102.87 ±2.11
	1	40	NA	24.73 ±0.52	311.20 ±5.67
	3	-18	NA	15.09 ±0.27	245.87 ±4.63
		5	NA	16.12 ±0.26	260.81 ±4.85
		23	NA	17.96 ±0.39	321.09 ±5.08
		40	NA	27.93 ±0.57	477.60 ±8.76
Szeged goulash	0	-	4.43 ±0.04	45.70 ±0.96	167.00 ±3.26
	1	40	NA	55.85 ±1.13	241.42 ±4.69
	3	-18	NA	48.23 ±0.99	208.84 ±4.07
		5	NA	50.77 ±1.07	218.39 ±4.23
		23	NA	53.31 ±1.10	236.07 ±4.58
		40	NA	60.93 ±1.27	299.71 ±5.02
Chicken meat	0	-	17.95 ±0.36	71.08 ±1.50	6.73 ±0.13
	1	40	NA	93.93 ±1.76	13.20 ±0.25
	3	-18	NA	88.85 ±1.52	11.87 ±0.21
		5	NA	91.39 ±1.68	12.33 ±0.20
		23	NA	93.20 ±1.71	15.53 ±0.24
		40	NA	106.62 ±1.97	29.81 ±0.63
Pate	0	-	8.66 ±0.13	30.46 ±0.59	28.20 ±0.59
	1	40	NA	53.37 ±1.08	39.73 ±0.78
	3	-18	NA	40.62 ±0.67	32.53 ±0.65
		5	NA	43.16 ±0.52	37.60 ±0.69
		23	NA	45.70 ±0.71	41.72 ±0.74
		40	NA	57.12 ±0.98	61.87 ±1.53
Tuna fish	0	-	22.13 ±0.41	68.54 ±1.40	30.80 ±0.61
	1	40	NA	76.16 ±1.49	56.23 ±1.37
	3	-18	NA	70.07 ±1.42	31.07 ±0.63
		5	NA	72.34 ±1.37	53.33 ±1.27
		23	NA	79.16 ±1.50	56.20 ±1.39
		40	NA	88.63 ±1.62	77.27 ±1.56

* Results are presented as means ± SD. NA – not analysed.

Results of sensory analysis are illustrated in Table 3. Appearance, consistency, flavour and off-flavour intensity were assessed in all foods. Firmness was evaluated only in cheese, baguette, chicken meat, pate and tuna fish. Potato purée worsened its flavour during the storage at the highest temperature; off-flavour was described as rancid and musty, which was probably caused by the presence of milk powder. Appearance, consistency and flavour were deteriorated through the storage of goulash soup at 40 °C; mainly owing to darkening, disintegrated croutons and unpleasant flavour. White-type cheese maintained its very good/good quality only when stored in a refrigerator.

Table 3 Results of sensory analysis during 3-month storage.

Food	Length of storage (months)	Temp. of storage (°C)	Appearance	Consistency	Firmness	Flavour	Off-flavour
Potato purée	0	-	2	2	NA	2	2
	1	40	2	2	NA	3	2
	3	-18	2	2	NA	2	2
		5	2	2	NA	2	2
		23	2	2	NA	4	4
		40	2	2	NA	6	6
Goulash soup	0	-	2	2	NA	2	1
	1	40	5	5	NA	3	2
	3	-18	2	2	NA	2	1
		5	2	4	NA	2	1
		23	2	4	NA	2	1
		40	5	6	NA	7	7
Cheese	0	-	1	1	4	1	1
	1	40	7	6	6	7	7
	3	-18	5	7	2	5	5
		5	2	2	4	2	2
		23	2	3	6	5	5
		40	7	6	7	7	7
Baguette	0	-	2	2	4	2	1
	1	40	2	3	4	4	2
	3	-18	4	4	4	4	2
		5	4	4	4	4	2
		23	2	3	4	4	3
		40	6	7	6	7	6
Szeged goulash	0	-	2	2	NA	1	1
	1	40	3	4	NA	5	4
	3	-18	2	3	NA	1	1
		5	2	2	NA	1	1
		23	2	2	NA	1	1
		40	3	3	NA	5	4
Chicken meat	0	-	1	1	4	2	1
	1	40	3	3	4	6	5
	3	-18	1	1	4	3	2
		5	1	1	4	3	2
		23	1	1	4	4	3
		40	3	3	5	6	5
Pate	0	-	3	3	3	3	1
	1	40	4	3	3	3	1
	3	-18	4	3	3	3	1
		5	4	3	3	3	1
		23	4	3	3	3	1
		40	4	3	3	4	2
Tuna fish	0	-	2	2	4	2	1
	1	40	3	3	4	3	2
	3	-18	2	3	4	2	1
		5	2	2	4	2	1
		23	2	2	4	2	1
		40	3	3	4	3	2

* Results are presented as medians. NA – not analysed.

Freezing caused undesirable appearance, consistency and flavour changes; thermostat storage led to unacceptable sensory quality concerning all features. Darkening of cheese stored in thermostat could be referred to Maillard browning **(Pizzoferrato et al., 1998; Kristensen et al., 2001)**. The connection between Maillard reactions and colour and flavour changes was proven by **Gaucheron et al. (1999)**. **Bubelová et al. (2015)** observed deteriorating of consistency and flavour of sterilized processed cheese due to high storage temperature (40 °C). Similarly, to white-type cheese, baguette samples stored at 40 °C were described as unacceptable after 3 months.

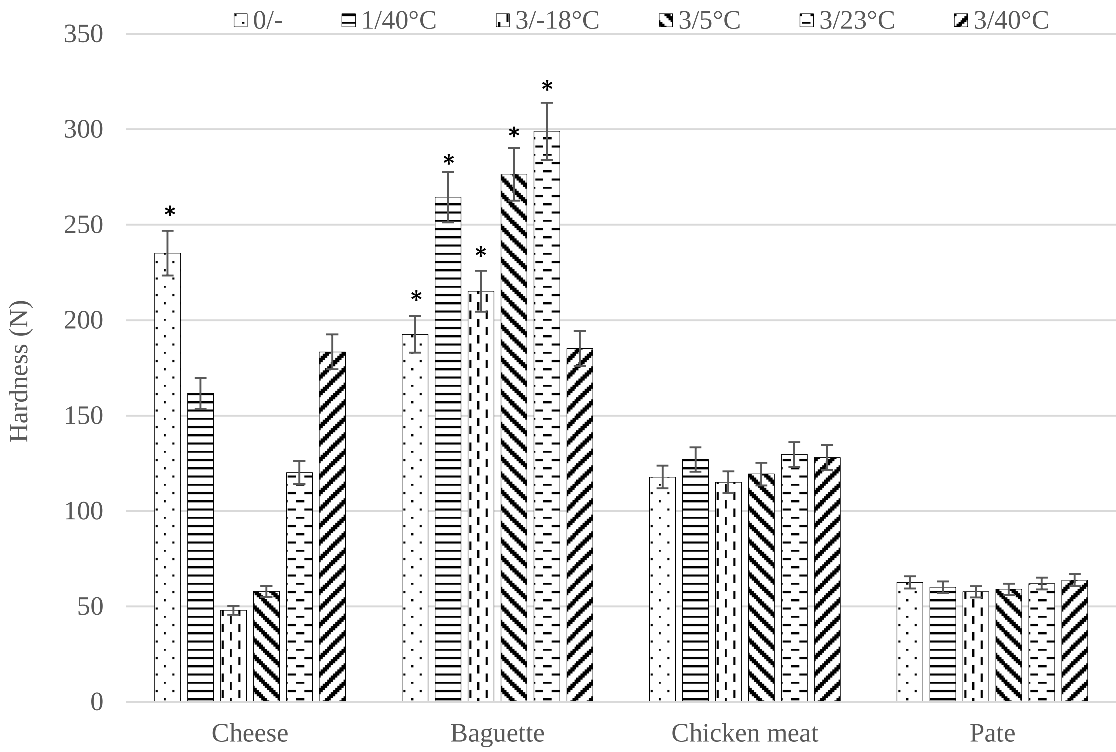

Figure 1 Results of hardness (N) during 3-month storage. Results are presented as means ± SD. Samples of cheese and baguette marked with asterisk (*) were compressed by 80%, other cheese and baguette samples by 50%.

Rashidi et al. (2016) published aroma and taste reduction through the storage of baguette bread. Ascending firmness of cheese and baguette (especially at 40 °C) correlated well with above mentioned hardness growth established during TPA analysis (see Figure 1). Szeged goulash and chicken meat worsened mainly their flavour when kept in thermostat. **Sepúlveda et al. (2003)** evaluated the sensory quality of beef-based meal-ready-to-eat during the storage at different temperatures. The authors concluded that elevated storage temperatures (27 and mainly 38 °C) negatively affected flavour and texture properties of beefsteak and beef stew. Worsening of overall sensory quality due to high storage temperature (38 °C) was mentioned also for black bean and rice burrito meal-ready-to-eat **(Rodríguez et al., 2003)**. Finally, pate and tuna fish retained very good or good overall sensory quality throughout 3-month storage at all temperatures. All four lastly mentioned foods (i.e. szeged goulash, chicken meat, pate and tuna) are cans; maintaining of acceptable sensory quality through long-term shelf-life (up to 4 years) could be expected due to sterilization process. However, thermostat storage did not seem suitable for szeged goulash and chicken meat.

CONCLUSION

The effect of four storage temperatures (simulating different climate conditions) on the quality of various types of food with long shelf-life was assessed during three-month storage. Most of the food products did not represent any microbial risk for the potential consumers. However, canned szeged goulash, pork pate and tuna fish, which should be free of microorganisms owing to sterilisation process, contained some counts of bacteria. These microorganisms presumably originated from spores that germinated during the thermostat storage. The storage in the freezer and in the refrigerator appeared to be the most suitable for most of the foods; products kept at these temperatures for three months maintained usually the best sensory quality and also shown the lowest ammonia and TBARS contents (markers of undesirable protein changes and lipid oxidation, respectively). One of the exceptions was frozen cheese whose appearance and consistency was evaluated negatively compared to samples stored at 5 and 23 °C. By contrast, thermostat storage was not appropriate for majority of the foods. Flavour (and in the case of some food products also appearance and consistency) impaired significantly throughout the 3-month storage at 40 °C and, simultaneously, ammonia and TBARS levels raised markedly. Thus, deamination reactions and oxidation of lipids proceeded more extensively at 40 °C. Based on these findings, it can be recommended to keep the foods at elevated temperature for a maximum period of one month. Finally, ambient storage seemed quite advisable for most of the foods, since the quality of majority foods stored at this temperature was better compared to the thermostat storage. The best sensory quality of all foods examined during the 3-month storage (regardless the storage temperature) was determined in pork pate and tuna fish. Amounts of both ammonia and TBARS did not enhance dramatically in these cans. On the other hand, the most excessive negative changes were detected in instant goulash soup, canned white-type cheese and pre-baked baguette. Current storage experiment is proceeding at the moment and will be evaluated as a whole after 2-year storage. Furthermore, different types of foods with long shelf-life (e.g. porridge, jam, honey, another instant foods and meal-ready-to-eat) will be chosen for additional trial with similar storage conditions.

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