

## Article

# Changes in the Mechanical, Sensory, and Microbiological Properties during the Storage of Innovative Vegetable and Meat Soups for Seniors

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**Abstract:** This study was conducted on vegetable soup with rabbit meat and vegetable soup with rabbit meat, beef balls, and carrots. The qualitative characteristics of the soups were adapted to the needs of elderly consumers. The soups used in the experiments were industrially produced. The aim of this study was to analyse changes in the mechanical, sensory, and microbiological properties of the soups occurring during their storage (1, 7, 14, and 21 days). Strength tests were performed at temperatures of 20 °C and 55 °C. Both soups had a high protein content (4.7–6.5%), low sugar (0.3–0.5%) and salt content (0.8%), and a fibre content of 1.4%. The texture analysis showed great similarity in the mechanical characteristics of both soups. The samples were characterised by low measured values for firmness (0.72 N) and cohesiveness (−0.14 N) in both temperatures. The average shear force of the beef balls with carrots at 20 °C was 12.3 N, but after heating, it decreased to 8.8 N ( $p < 0.05$ ). The rheological tests on the soups showed that they were characterised by a relatively high viscosity (15–20 Pas at 55 °C). Storage of the soups for 21 days did not significantly affect their rheological parameters ( $p > 0.05$ ). The soup with beef balls and carrots was rated higher by the sensory panel. On the 21st day of storage, the permitted limit of the count of bacteria was not exceeded in either of the samples. This study shows that the soups had desirable structural, nutritional, and sensory characteristics, which are important for this group of consumers. The values of the mechanical parameters of all the samples were low, and they were even significantly more reduced when the products were heated. This may suggest that the products should not be difficult to consume for seniors.

**Keywords:** innovative soup; aged people; physicochemical properties; texture profile; rheology; sensory evaluation



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## 1. Introduction

The ageing of society is a long-term trend which began in Europe several decades ago. This phenomenon is manifested by transformation in the age structure of the population. The percentage of elderly people is increasing, while the share of the working age population in the total population is decreasing. In 2019, more than one fifth (20.3%) of the European Union (EU-27) population was 65 years or older. Between 2019 and 2100, the percentage of people aged 80 or more in the EU-27 is expected to increase 2.5 times from 5.8% to 14.6% [1]. According to the United Nations, between 2019 and 2050, the number of people aged over 65 years around the world is forecast to almost double.

In recent years, highly developed countries have also been particularly concerned about the diets of elderly consumers. According to Platta [2], people aged over 65 years

enjoyed the consumption of turkey, chicken, rabbit, and veal. Half of their total demand for protein should be satisfied by the consumption of lean meat, as they tend to suffer from sarcopenia [3,4]. Because the food preferences of older adults are well established [5], they are more likely to maintain traditional food habits and choices, such as regular consumption of meat and dairy products. Red meat is a high biological value protein source and is nutritionally balanced with micronutrients such as iron, zinc, selenium, potassium, and a range of B vitamins. Because it forms a traditional part of the diets of many elderly people, red meat is a suitable vehicle for further fortification with nutrients targeted at elderly people, such as protein [6]. On the other hand, the social and economic changes of the past few years are leading to an increased interest in rabbit meat products. Rabbit meat has excellent nutritional features, such as high protein content, low fat content, and a high percentage of unsaturated fatty acids, low cholesterol, and sodium. Therefore, rabbit meat is highly recommended for pregnant women, adolescents, and aged people [7].

However, the role of vegetables in the diet should also be remembered. The National Centre for Nutrition Education prepared recommendations on the nutrition of elderly people and dietary recommendations for them in the form of a 'new plate', where the role of vegetables in the diet was emphasised [8,9]. In light of these recommendations, it seems justified to implement plant ingredients into meat products in order to increase their dietary value. Vegetables provide various nutrients such as potassium, folates, magnesium, zinc, selenium, provitamin A, and vitamin C, which are necessary to maintain good health [10,11].

When discussing food products for seniors, it is important to ensure that they have appropriate textures so that consumers with impaired food crushing and swallowing functions can enjoy eating without the need to eliminate difficult-to-chew foodstuffs from their diets. It is also important to remember that the taste and smell of the product should be appropriately intensified. Therefore, it is necessary to adapt the daily diets of elderly consumers to their needs [12,13]. Foods with modified structures should favour safe consumption [14,15]. Soup-based products are interesting food preparation solution for the elderly, since they are easy to swallow and can fortify any functional ingredients or micronutrient deficiency to meet the body's requirements. This will be more beneficial for elderly populations and worth preventing and promoting health rather than curative care [16].

Each food product has its own rheological characteristics. Despite numerous attempts to quantify the sensory properties of food materials on the basis of the physical measurements and chemical characteristics of products [17], the results were not fully satisfactory. It is believed that the structure and rheological behaviour of products may be considerably influenced by the conditions during their modification in the mouth [18]. Most food products have both viscous (liquids) and elastic (solids) properties and are referred to as viscoelastic materials [19]. Such rheological characteristics may affect the swallowing process because they influence food transport in the body [20].

Seniors are a dynamically growing group of consumers with specific needs and preferences. It seems that the food sector should target its activities at different age groups, including seniors, and adapt their products to their needs. This belief was the basic premise for our research. The main goal of the study was to analyse changes in the textural, rheological, sensory, and microbiological properties of innovative vegetable and meat soups for seniors occurring during the storage of these products.

## 2. Materials and Methods

### 2.1. Material and Technology of Production of Model Soups

Our study involved an experiment on meat and vegetable soups categorised as ready-made meals. Vegetable cream soup with rabbit meat and vegetable cream soup with rabbit meat and beef balls with carrots were prepared according to the design assumptions and produced industrially according to the applicable quality standards. The main ingredients were uncured minced rabbit meat, vegetables (potatoes, carrots, parsley, leeks, celery, and

parsnips), and spices. Additionally, meatballs made from minced beef with carrots were prepared for the other soup variant. A special device was used to form balls from the meat batter. The meatballs were of equal weight so as to precisely add them to the soup according to the recipe.

In the first stage of the technological process, broth from rabbit meat, vegetables, and spices was cooked in a pot. Next, the entire meat and vegetable mass was comminuted in a cutter to obtain a homogeneous structure. After that, the soup was dispensed into thermostable trays, which were closed with a barrier foil. The products were pasteurised for a specified period of time at an appropriate temperature and stored for 21 days at a temperature of  $4 \pm 2$  °C.

## 2.2. Basic Composition Analysis

The model soups were analysed for the content of the following components: protein [21], fat [21], sugar [21], sodium chloride [21], saturated fatty acids [22], and dietary fibre [23]. The total carbohydrate content was calculated according to the following formula:

$$X_1 = 100 - (W + F + P + A) \quad (1)$$

where  $X_1$  is the total carbohydrates (%),  $W$  is water (%),  $F$  is fat (%),  $P$  is protein (%), and  $A$  is ash (%).

The energy values of the products were calculated with the conversion factors specified in Annex XIV of Regulation (EU) No. 1169/2011 [24]. The basic composition was tested on the first day of storage of the soups, and they were measured in 6 replicates.

## 2.3. Texture Measurement

The textures of the tested samples were instrumentally assessed with a TA-XT2i Texture Analyser (Stable Micro Systems, Ltd., Godalming, UK). The texture of the soups were tested at a temperature of about 20 °C ( $\pm 1$  °C) and after heating the samples to about 55 °C ( $\pm 1$  °C). The textures of the cream soups were assessed for homogeneity with a penetration test which determined the following parameters: firmness (N), consistency (N), cohesiveness (N), and index of viscosity ( $N \times s$ ). A P/35 cylinder with a diameter of 35 mm (Surrey, England) was used as a pin, which penetrated the sample to a depth of 40% of its initial height. The following texturometer settings were used: a test speed of 1.0 mm/s, distance of 20 mm, trigger force of 5 g, and data acquisition rate of 200 PPS.

The texture of the beef balls was assessed in a shear force test with an HDP/BS Warner-Bratzler blade (Stable Micro Systems, Godalming, UK), which enabled the measurement of the maximum shear force (N). The following texturometer settings were used: a test speed of 1.5 mm/s, distance of 10 mm, trigger force of 5 g, and data acquisition rate of 200 PPS. All texture determinations were measured in 8 replicates.

## 2.4. Rheological Analysis

In order to determine the rheological properties of the soups, oscillatory rheology and a DMWT—COBRABID rheological analyser (COBRABiD—Poznań, Poland, 2011) were used (DMA). A cone-plate measurement system ( $f = 0.03$  m,  $\alpha = 6^\circ$ ) was used to analyse the soups. The measurements were made at room temperature (about 20 °C) and during heating from 10 °C to 60 °C. The samples were heated at a rate of 2.0 °C per min. The accuracy of the temperature measurement in the chamber and measuring plate was  $\pm 0.2$  °C.

The following components of the complex shear modulus were determined: the elastic modulus ( $G'$ ), dynamic viscosity ( $\eta$ ), and loss tangent ( $\tan \delta$ ). The tests were conducted for two frequencies of the forcing mechanical field  $f = 2.6$  Hz. The rheomechanical parameters were analysed within the linear range of viscoelastic properties of each sample.

The dependence of the dynamic viscosity on the shear rate was determined with a programmable rotational ViscoQC 300 viscometer (Anton Paar GmbH, Graz, Austria). The tests were conducted at temperatures of  $20 \pm 0.5$  °C and  $55 \pm 0.5$  °C. The DG26 double-

gap system was used with an L1 spindle. The spindle speed ranged from 7 to 100 rpm, increasing gradually. This corresponded to shear rates of 10–129 L/s. In order to stabilise the viscosity, the measurement was recorded after 1 min. The rheological parameters were measured in 6 replicates.

### 2.5. Sensory Evaluation

The sensory attractiveness of the products was measured with the scaling method according to PN-ISO 4121:1998 [25]. Consumer evaluation according to a hedonic scale was applied. Consumer preferences regarding the overall acceptability of the product were evaluated according to the following scale: I love it (9 points); I like it very much (8 points); I mostly like it (7 points); I quite like it (6 points); I neither like nor dislike it (5 points); I do not like it a little (4 points); I mostly do not like it (3 points); I really do not like it (2 points); and I hate it (1 point).

Both the overall acceptability of the product and the acceptability of individual characteristics (appearance, colour, smell, taste, consistency, and overall acceptance) were evaluated. The products were evaluated by a group of 15 consumers (7 men and 8 women) who had not received any sensory training. The consumer's age was the criterion for selection of members of the group. The average age of the evaluators was 67 years. The characteristics of the products were assessed after heating. The sensory analysis was measured in 30 replicates.

### 2.6. Microbiological Analysis

The following methods were used for the microbiological analysis of the model soups: the total count of aerobic mesophilic microorganisms [26], the presence of *Salmonella* spp. [27], the presence of *Listeria monocytogenes* [28], and the count of mesophilic lactic acid [29]. The microbiological analysis was measured in 6 replicates.

### 2.7. Statistical Analysis

Statistica 13.1 software (StatSoft, Tulsa, OK, USA) was used for statistical analyses. Differences were considered significant at  $p < 0.05$ . The distribution of variables was examined with the Shapiro–Wilk test. Multivariate analysis of variance (ANOVA) was used to assess the effect of the storage time and sample type on changes in the texture characteristics of the samples. Tukey's test was used for pairwise comparisons of means for significant factors. Pearson's correlation coefficients ( $r$ ) and the contingency coefficient were also calculated to examine the correlations for qualitative variables in the interpretation of the results of sensory analysis. Principal component analysis (PCA) was used to visualise the data and detect interdependencies between variables. The experiment was repeated two times, and the determinations of each analysis were carried 3, 4, or 15 times in each sample.

## 3. Results and Discussion

### 3.1. Basic Composition and Nutritional Value

The recipes for innovative soups based on meat and vegetables were developed by reformulating and implementing bioactive substances with beneficial effects on the body's functioning. A statistically significant higher protein content was found in the vegetable cream soup with rabbit meat and beef balls with carrots (6.5%) than in the soup without beef (4.7%) ( $p < 0.05$ ). The contents of the other ingredients did not differ significantly. The model soups were in line with the general nutritional recommendations for elderly consumers. They had a high protein content (5.6% on average) and low levels of sugars (0.4% on average) and salt (0.8% on average). They were a source of dietary fibre (1.4% on average) ( $p < 0.05$ ). The contents of individual ingredients and the nutritional values of the soups are listed in Table 1.

In an earlier study [30], commercial soups for seniors purchased in Japan were analysed. These were two products: creamed pork and vegetable soup and creamed chicken and vegetable soup (homogenous products) (Maruha Nichro Co., Tokyo, Japan). They were

prepared for seniors with chewing problems. The manufacturer offered the soups in 75 g hermetic packages which had the following nutritional values: 75 and 77 kcal, 2.4 and 3.6 g of protein, 5.4 and 5.3 g of fat, 3.8 and 3.5 g of sugar, 0.7 and 0.5 g of fibre, and 0.6 and 0.5 g of salt, respectively. The innovative soups (per 75 g of product) had higher contents of protein (by about 1.2%) and fibre (by about 0.6%), a similar amount of salt (0.6%), and lower contents of sugar (by about 3%) and fat (by about 2.0%).

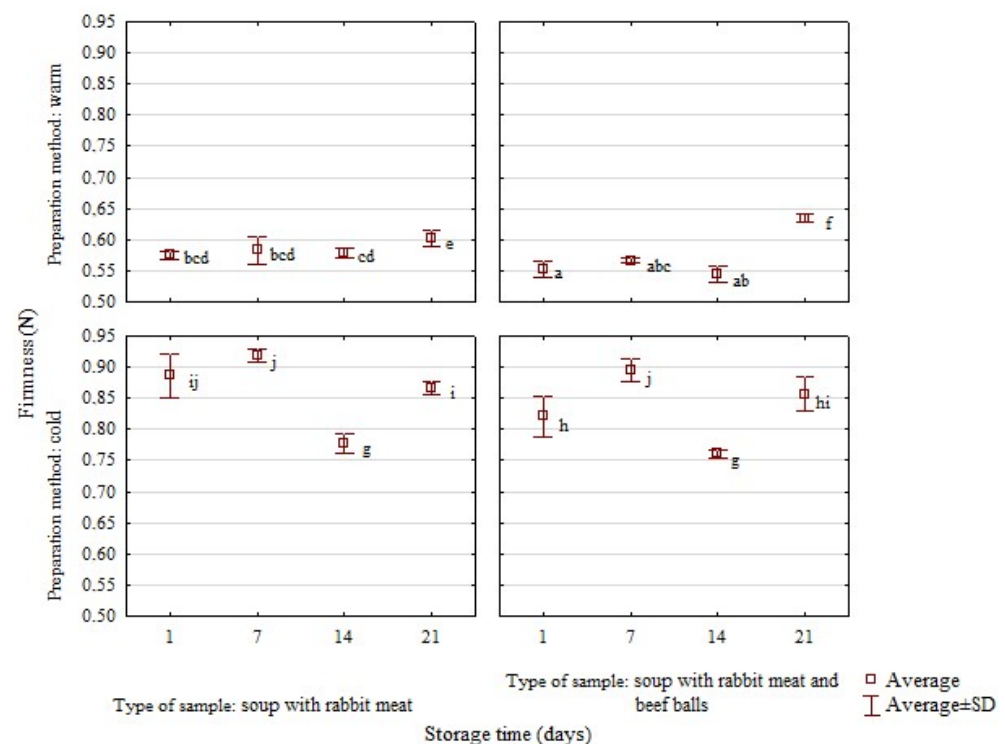
**Table 1.** A commercial specification of the innovative soups, showing ingredients and nutritional values.

| Ingredients              | Vegetable Cream Soup with Rabbit Meat |        | Vegetable Cream Soup with Rabbit Meat and Beef Balls with Carrots |        |
|--------------------------|---------------------------------------|--------|-------------------------------------------------------------------|--------|
|                          | 100 g/product                         | % RI * | 100 g/product                                                     | % RI * |
| Nutritional values       | 100 g/product                         |        | 100 g/product                                                     |        |
| Energy value             | 350 kJ/84 kcal                        | 18     | 373 kJ/89 kcal                                                    | 19     |
| Fat, including           | 4.5 g                                 | 6      | 4.5 g                                                             | 6      |
| saturated fatty acids    | 1.8 g                                 | 9      | 1.8 g                                                             | 9      |
| Carbohydrates, including | 5.5 g                                 | 2      | 5.0 g                                                             | 2      |
| Sugar                    | 0.5 g                                 | 1      | 0.3 g                                                             | 0      |
| Dietary fibre            | 1.3 g                                 | -      | 1.4 g                                                             | -      |
| Protein                  | 4.7 g                                 | 9      | 6.5 g                                                             | 13     |
| Sodium chloride          | 0.8 g                                 | 14     | 0.8 g                                                             | 14     |

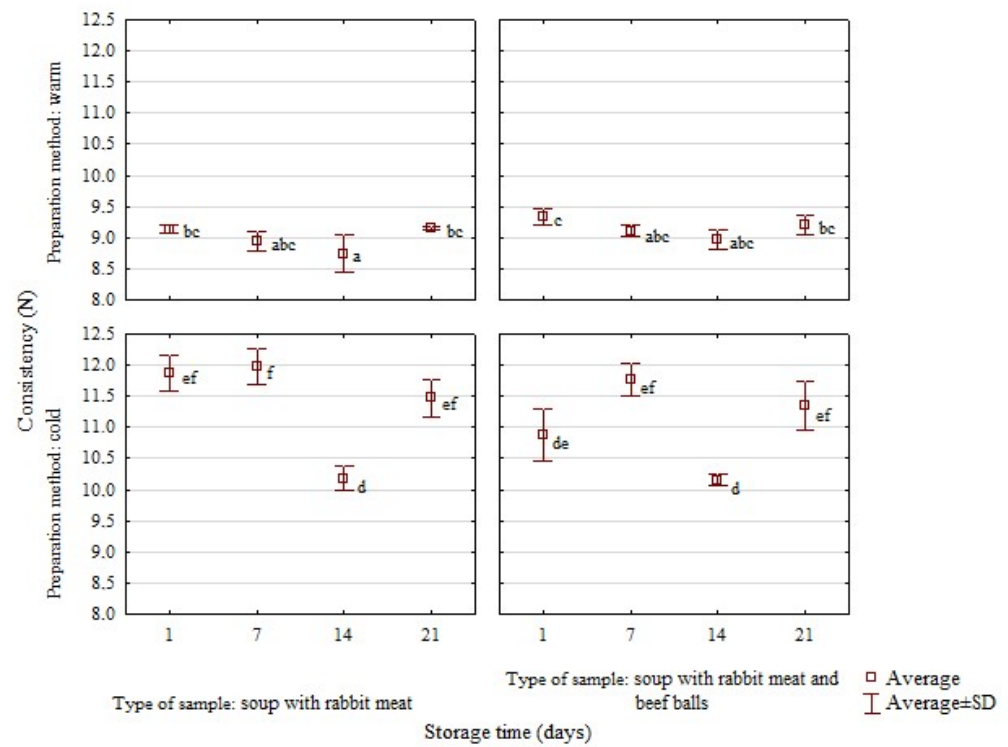
\* Reference intake for an average adult (8400 kJ/2000 kcal).

### 3.2. Texture Analysis

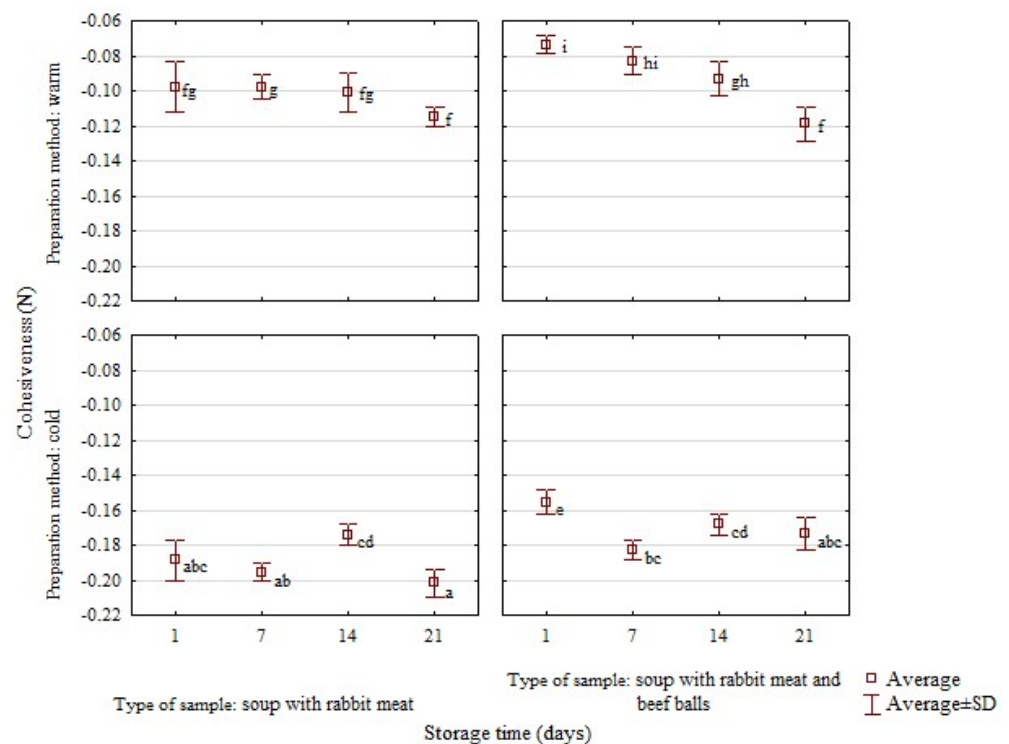
In terms of food technology, the texture of food products is significantly determined by their rheomechanical properties [31]. Each soup released on the market should be clearly identified by the distinct taste of its main ingredient and an appropriate texture. Generally, there are two types of soups: thick and clear (thin) ones. Soups are categorised into either type by assessing their textures [32]. The textures of the two model soups were tested at room temperature (20 °C) and after heating (55 °C). The results are shown in Figures 1–4.



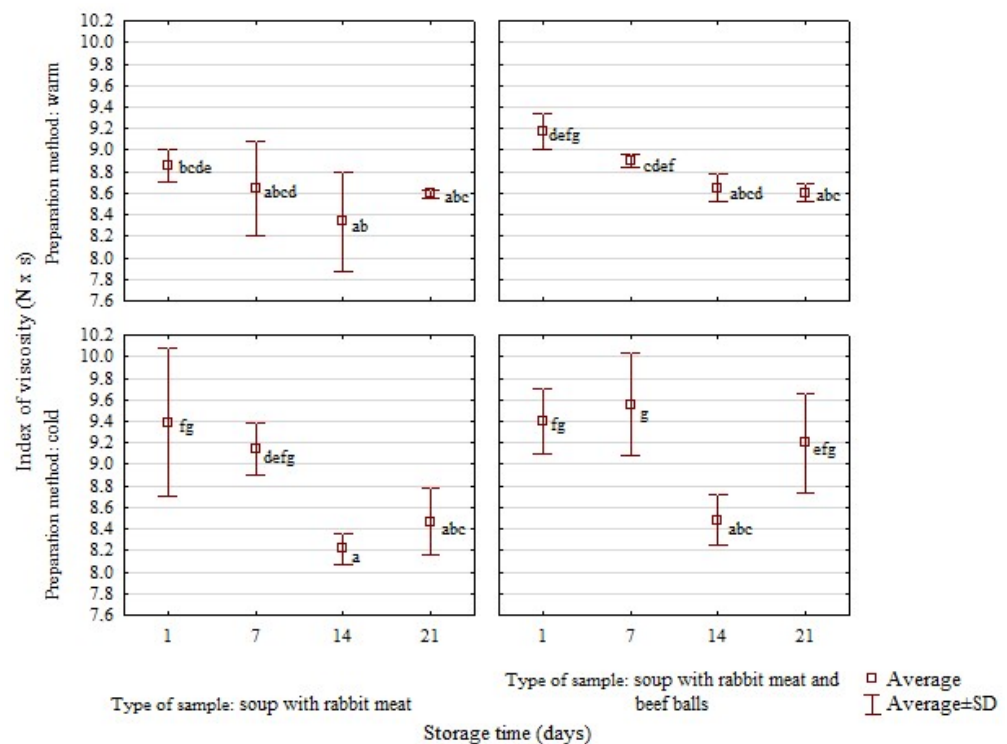
**Figure 1.** The firmness of the model soups measured at room temperature and after heating vs. the storage period. (a–j) Different letters indicating a significant difference at  $p < 0.05$  (n = 8).



**Figure 2.** The consistencies of the model soups measured at room temperature and after heating vs. the storage period. (a–f) Different letters indicating a significant difference at  $p < 0.05$  ( $n = 8$ ).



**Figure 3.** The cohesiveness of the model soups measured at room temperature and after heating vs. the storage period. (a–i) Different letters indicate a significant difference at  $p < 0.05$  ( $n = 8$ ).



**Figure 4.** The indices of viscosity of the model soups measured at room temperature and after heating vs. the storage period. (a–g) Different letters indicate a significant difference at  $p < 0.05$  ( $n = 8$ ).

Both model soups were characterised by a similar firmness at room temperature (Figure 1). The average values amounted to  $0.85 \pm 0.02$  N on day 1,  $0.91 \pm 0.02$  N on day 7,  $0.77 \pm 0.01$  N on day 14, and  $0.86 \pm 0.02$  N on day 21. When the soups were heated, the values of all texture parameters decreased significantly. However, although there were statistically significant differences, the numerical values were similar ( $p < 0.05$ ). The firmness, expressed as the average value measured for two variants of samples at all storage periods, decreased to  $0.58 \pm 0.01$  N.

During storage, the course of changes in the consistency of both soups measured at room temperature and after heating was quite similar to the course of changes in firmness (Figure 2). At  $20^\circ\text{C}$ , there were greater differences in the consistency for individual storage periods. The average maximum ( $11.8 \pm 0.2$  N  $\times$  s) and minimum values ( $10.2 \pm 0.1$  N  $\times$  s) for both soups were observed on the seventh day of storage ( $p < 0.05$ ). The analysis of the texture of the samples after heating showed equal values for the consistency of both soups during individual storage periods. They ranged from  $8.7 \pm 0.1$  N  $\times$  s to  $9.4 \pm 0.1$  N  $\times$  s ( $p > 0.05$ ).

Figure 3 shows the values of another texture parameter (i.e., cohesiveness). During the same storage periods, both soup samples were characterised by similar values for this texture parameter. Like before, after heating, the values of cohesiveness were statistically significantly lower than at room temperature ( $p < 0.05$ ).

The viscosity index was the last texture parameter analysed in our study (Figure 4). Both at room temperature and after heating, the average viscosity of the soup with beef balls was 0.3 greater than that of the other soup (the average value measured in the four storage periods). At both temperatures, the values of the viscosity index tended to decrease slightly for subsequent storage periods. This may have been caused by a gradual release of water from the tested systems, which caused their dilution as the storage period extended. At the same time, the test temperature had minimal influence on the decrease in the viscosity index. In terms of mechanical properties, the model soups were quite similar to the commercial soups released on the Japanese market [30].

Both at room temperature and after heating, the values of the texture parameters of the model soups tested in our study were slightly lower than those of commercially available soups. The latter were characterised by higher average density and viscosity values. This effect may have been caused by the addition of thickeners to these products or different amounts or types of vegetables to make the vegetable pulp, which also determined the density and consistency of the soups. Japanese soups can be classified as thick soups. Depending on the type of thickener, thick soups are classified as purées (vegetable soups thickened with starch), bisques (made from shellfish or vegetable purée thickened with cream), cream soups (thickened with béchamel sauce), and veloutés (thickened with eggs, butter, or cream) [33]. As was the case with the model soups, the heating of the commercial soups caused a statistically significant decrease in the values of the texture parameters (except cohesiveness) ( $p < 0.05$ ). As most soups, especially thick cream soups, are eaten hot, such a change in texture meets the expectations of elderly consumers, who can swallow them more easily.

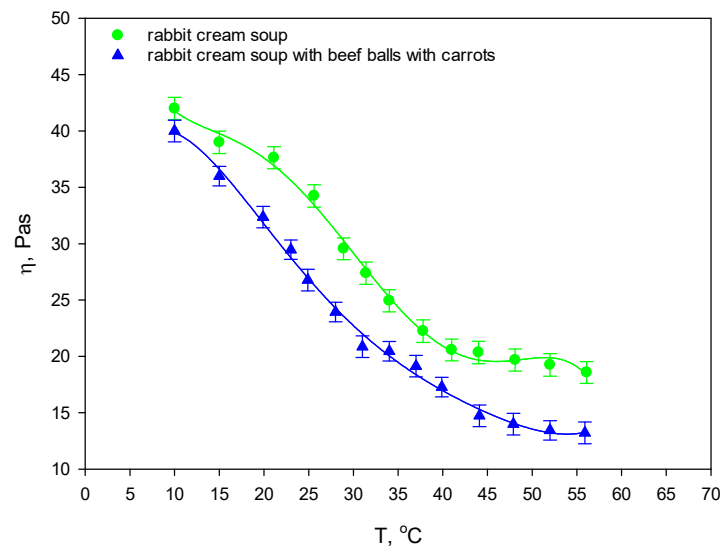
Another noteworthy parameter was the value of the shear force of the meat added to one of the model soups. The average shear force of the beef balls with carrots at 20 °C was  $12.3 \pm 0.2$  N. When heated to about 55 °C, the shear force decreased to  $8.8 \pm 0.1$  N on average ( $p < 0.05$ ). These values remained at a similar level throughout the entire period of storage for this soup. In earlier analyses, the shear forces of the beef cubes in goulash measured at 20 °C and 55 °C were 13.8 N and 10.4 N, respectively [30]. As can be seen, the beef balls from the model soup were not as hard as the meat pieces from the commercial product. It is important to note that the meat pieces in both soups were of a similar size. The structure of minced meat and the balls formed from it fully meet the requirements of consumers who find it difficult to bite and chew solid elements in food. The meat in the soup was easily crushed into smaller pieces with the tongue or gums only.

### 3.3. Rheological Analysis

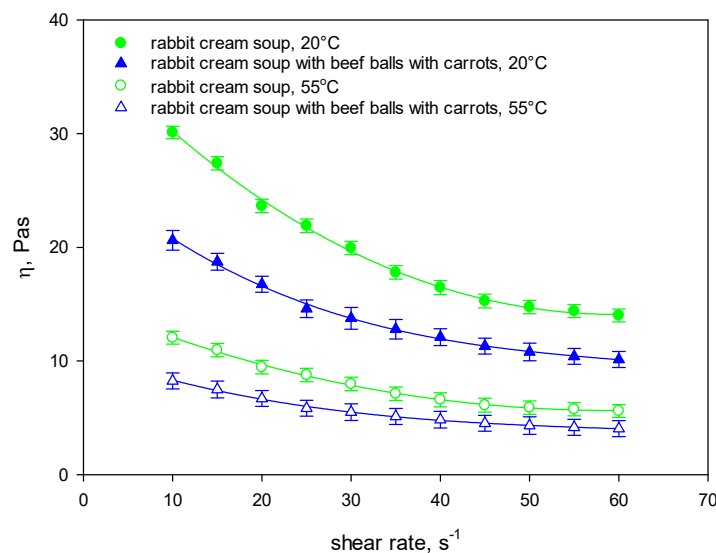
From a physicochemical point of view, the soups analysed in our study were dispersion systems [34]. The vegetable pulp constitutes a dispersed phase, whereas the soluble plant ingredients with the soluble animal proteins contained in the decoction are a continuous phase. The rheological properties of such systems result from the interaction between these two phases. They depend on the type and amount of soluble solids in the continuous phase, as well as the volume fraction of insoluble solid particles and their size [35,36]. The effective volume fraction of particles depends on their parameters, such as the size, morphology, hardness, and force of interactions between particles. On the one hand, intermediate sizes for particles and a considerable variety of particle sizes increase the viscosity and yield point. On the other hand, a smaller size for particles may cause a decrease in the viscoelastic moduli [37–39].

Soups are usually eaten hot. As the vegetables in the model soups were homogenised to a similar extent, the differences in the temperature patterns of the rheological determinants were determined by the density of the vegetable pulp and the density of the ingredients dissolved in water. The dynamic viscosity  $\eta$  of the model soup systems (Figure 5) showed that they were characterised by a relatively high density and, consequently, viscosity. However, the value of this parameter was significantly reduced by heating.

Within the entire range of temperatures under analysis, the values of the dynamic viscosity of the cream soup with beef balls were lower than those of the cream rabbit soup. In the results from the curves showing the relationship between the viscosity and shear rate (Figure 6), the dynamic viscosity  $\eta$  of the soups decreased as the shear rate increased. The relationship between the viscosity and shear rate can be used to classify foods as Newtonian, non-Newtonian, pseudoplastic, dilatant, thixotropic, or rheopectic. This classification is useful in processing, quality control, sensory evaluation, and structural analysis. The relationship between the shear rate and dynamic viscosity of the vegetable soup with rabbit meat and the soup with rabbit meat and beef was determined at 20 °C and 55 °C on the first day after preparation and on the 21st day of storage.



**Figure 5.** Changes in the dynamic viscosity  $\eta$  of the model soup systems during heating. Values expressed as means  $\pm$  SD ( $n = 6$ ).



**Figure 6.** Changes in the dynamic viscosity  $\eta$  of the model soup systems at different shear rates. Values expressed as means  $\pm$  SD ( $n = 6$ ).

The Ostwald–de Waele power model in Equation (2) was applied to describe the viscosity curves:

$$\eta = K \dot{\gamma}^n \quad (2)$$

where  $\eta$  (Pa·s) is the dynamic viscosity,  $K$  (Pa·s <sup>$n$</sup> ) is the consistency factor,  $\dot{\gamma}^{(1/s)}$  is the shear rate, and  $n$  (-) is the flow indicator showing the type of liquid [40].

For Newtonian fluids,  $n = 1$ ; for non-Newtonian, shear-thinning fluids,  $0 < n < 1$ ; and for pseudoplastic fluids,  $n > 1$  [41].

Table 2 shows the parameters for fitting the apparent viscosity curves  $\eta$  of the model soup systems at different shear rates shown in Figure 6 for the Ostwald–de Waele rheological model.

**Table 2.** The coefficients of the Ostwald–de Waele rheological model (viscosity curves).

| Storage Time | Type of Sample                                    | Temperature | K (Pas <sup>n</sup> )     | n (-)                         | R <sup>2</sup> |
|--------------|---------------------------------------------------|-------------|---------------------------|-------------------------------|----------------|
| 1 day        | Soup with rabbit meat                             | 20 °C       | 29.58 <sup>a</sup> ± 1.21 | 0.3648 <sup>a</sup> ± 0.0471  | 0.99           |
|              |                                                   | 55 °C       | 20.37 <sup>d</sup> ± 0.94 | 0.2261 <sup>b</sup> ± 0.0214  | 0.98           |
|              | Soup with rabbit meat and beef balls with carrots | 20 °C       | 25.35 <sup>b</sup> ± 1.07 | 0.1918 <sup>bc</sup> ± 0.0175 | 0.99           |
|              |                                                   | 55 °C       | 16.63 <sup>e</sup> ± 0.39 | 0.1463 <sup>d</sup> ± 0.0098  | 0.97           |
| 21 days      | Soup with rabbit meat                             | 20 °C       | 27.16 <sup>b</sup> ± 1.11 | 0.3184 <sup>a</sup> ± 0.0398  | 0.98           |
|              |                                                   | 55 °C       | 16.33 <sup>e</sup> ± 0.32 | 0.2007 <sup>b</sup> ± 0.0203  | 0.99           |
|              | Soup with rabbit meat and beef balls with carrots | 20 °C       | 22.37 <sup>c</sup> ± 1.01 | 0.1812 <sup>c</sup> ± 0.0146  | 0.99           |
|              |                                                   | 55 °C       | 14.52 <sup>f</sup> ± 0.28 | 0.1217 <sup>e</sup> ± 0.0082  | 0.96           |

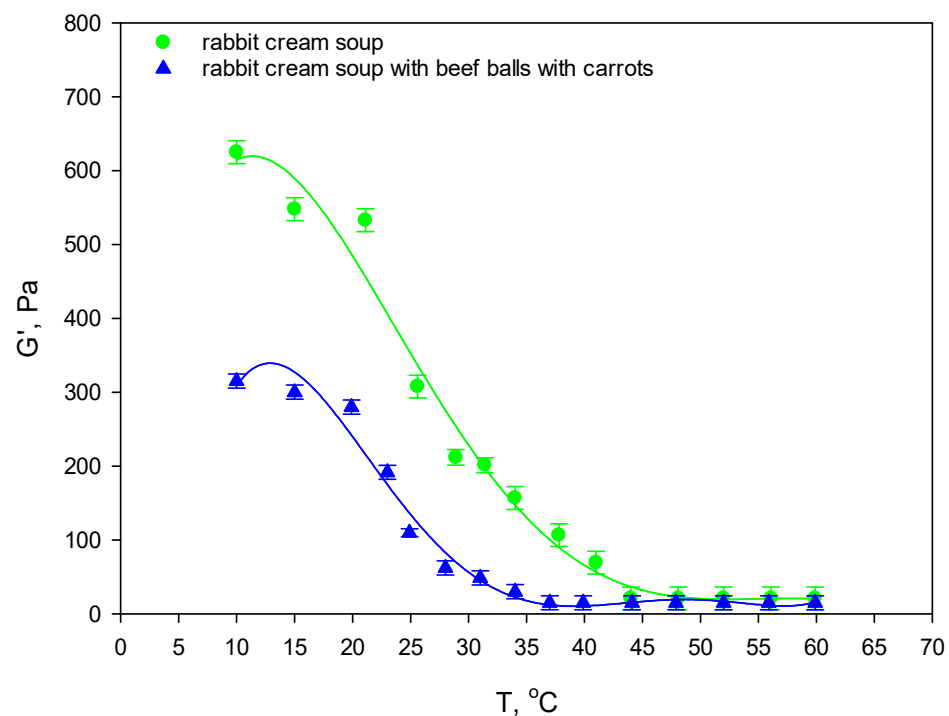
(<sup>a–f</sup>) Different superscript letters indicate a significant difference at  $p < 0.05$  (mean ± SD;  $n = 6$ ).

The fitting factors of the viscosity curves  $\eta$  showed that the model vegetable soups had a noticeable pattern of apparent viscosity, which could be characterised within the non-Newtonian behaviour of pseudoplastic flow (shear-thinning systems). The higher K values of the rabbit soup show that it was more viscous than the soup with beef balls with carrots due to the greater apparent viscosity and density.

In the results from the analysis of changes in the dynamic viscosity observed during the heating of the model soups, the differences in the values of this rheological parameter may have been caused by different densities for the vegetable pulps contained in the soups. They may also have been caused by differences in the share of starch in the continuous phase during processing. The starch was extracted from potatoes, which were an ingredient of the vegetable pulp. The difference in the content of animal proteins in the concoctions of both soups may be of similar significance.

As mentioned above, the viscoelastic properties of the suspension were determined by the rheological characteristics of both the continuous and dispersed phases. This fact was confirmed by the analysis of the course of changes in the modulus of elasticity  $G'$  (Figure 7) during heating. At low temperatures (i.e., up to about 20 °C), the model soups exhibited an elastic response. The samples were more elastic than viscous. As the temperature increased, the system became liquefied. This means that the forces holding the particles of the system together were overcome, and they changed their positions. The modulus of elasticity  $G'$  determined during the measurements was a reflection of the stiffness of the model systems, resulting from their density rather than a measure of their elastic properties. This was related to the consistency of the system. In the results from the course of changes in the temperature of this determinant, the cream soup with beef balls became liquid at slightly lower temperatures than the cream rabbit soup.

The cold storage of the model soups for 21 days did not change their rheological characteristics. However, their viscosity values decreased significantly (Table 3) both at room temperature and at 55 °C. The innovative soups had similar rheological properties to the commercial soups for seniors [30]. Some differences may have been caused by the use of thickeners in the commercial products (modified starch and xanthan gum), which had not been added to the model products. Modified starch thickeners are commonly used in a wide range of processed products available on the market, including soups [42]. Starch and gum additives increase the elastic properties of soups. This is important because elderly people with swallowing dysfunctions perceive thickened liquids as easier to consume and creamier than low-viscosity soups. According to sensory and rheological studies, creaminess may be related to the viscosity of the tested systems [43].



**Figure 7.** Changes in the modulus of elasticity  $G'$  of the model systems during heating. Values expressed as means  $\pm$  SD ( $n = 6$ ).

**Table 3.** The dynamic viscosity  $\eta$  (Pas) of the cream soups.

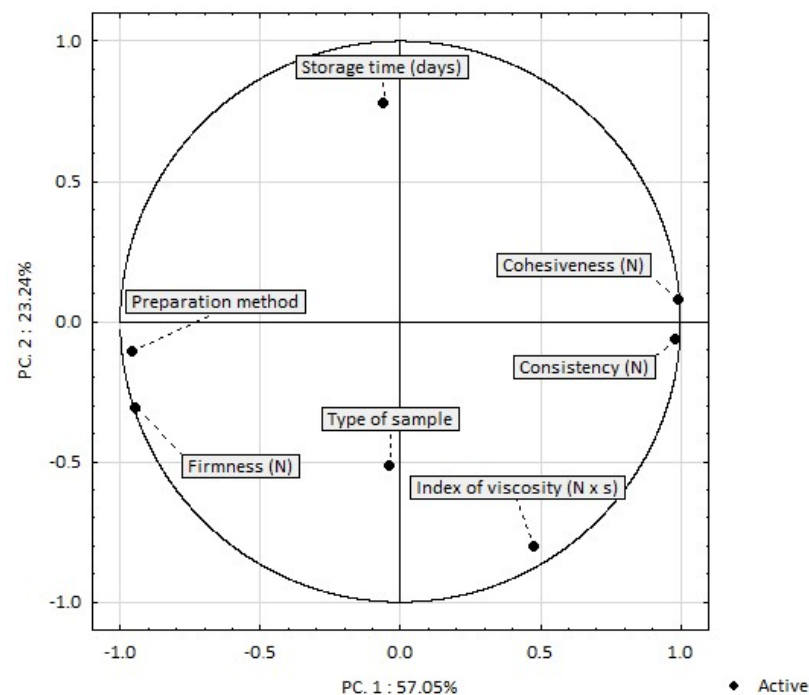
| Type of Sample                                    | Temperature | 1 Day                         | 7 Day                          | 14 Day                        | 21 Day                        |
|---------------------------------------------------|-------------|-------------------------------|--------------------------------|-------------------------------|-------------------------------|
| Soup with rabbit meat                             | 20 °C       | 37.63 <sup>a</sup> $\pm$ 1.61 | 33.24 <sup>b</sup> $\pm$ 1.42  | 29.11 <sup>c</sup> $\pm$ 1.13 | 25.38 <sup>d</sup> $\pm$ 1.12 |
|                                                   | 55 °C       | 18.21 <sup>f</sup> $\pm$ 0.98 | 16.14 <sup>g</sup> $\pm$ 0.75  | 15.23 <sup>g</sup> $\pm$ 0.58 | 13.22 <sup>h</sup> $\pm$ 0.72 |
| Soup with rabbit meat and beef balls with carrots | 20 °C       | 29.03 <sup>c</sup> $\pm$ 1.11 | 27.47 <sup>cd</sup> $\pm$ 1.31 | 25.54 <sup>d</sup> $\pm$ 1.26 | 22.30 <sup>e</sup> $\pm$ 0.87 |
|                                                   | 55 °C       | 16.21 <sup>g</sup> $\pm$ 0.84 | 15.75 <sup>g</sup> $\pm$ 0.67  | 13.02 <sup>h</sup> $\pm$ 0.70 | 11.69 <sup>i</sup> $\pm$ 0.54 |

(<sup>a–i</sup>) Different superscript letters indicate a significant difference at  $p < 0.05$  (mean  $\pm$  SD;  $n = 6$ ).

### 3.4. Principal Component Analysis (PCA)

The principal component analysis enabled the presentation of the relationships between the samples in one chart. The PCA was based on all research results. The chart below (Figure 8) shows the results of the PCA based on correlation for the two samples of model soups (rabbit cream soup and rabbit cream soup with beef balls) stored for 21 days in two variants of texture analysis (i.e., cold and hot). PC 1 (57.05%) and PC 2 (23.24%) explained 80.29% of the total variance.

The firmness and consistency results formed separate clusters, indicating a positive correlation. Moreover, neither the firmness nor consistency were correlated with the type of sample or storage time. The loading signs indicate that the firmness and consistency were negatively correlated with the method of preparation (different test temperatures) and cohesiveness. There was a rather weak positive correlation between the viscosity index and the consistency values. The viscosity index was negatively correlated with the storage time. The values of the viscosity index tended to increase along with the soup storage period. On the other hand, the heating of the samples resulted in higher cohesiveness but a lower firmness and consistency.



**Figure 8.** Selected soup texture characteristics vs. the type of sample, preparation method (cold and hot), and storage time for principal component analysis and loadings.

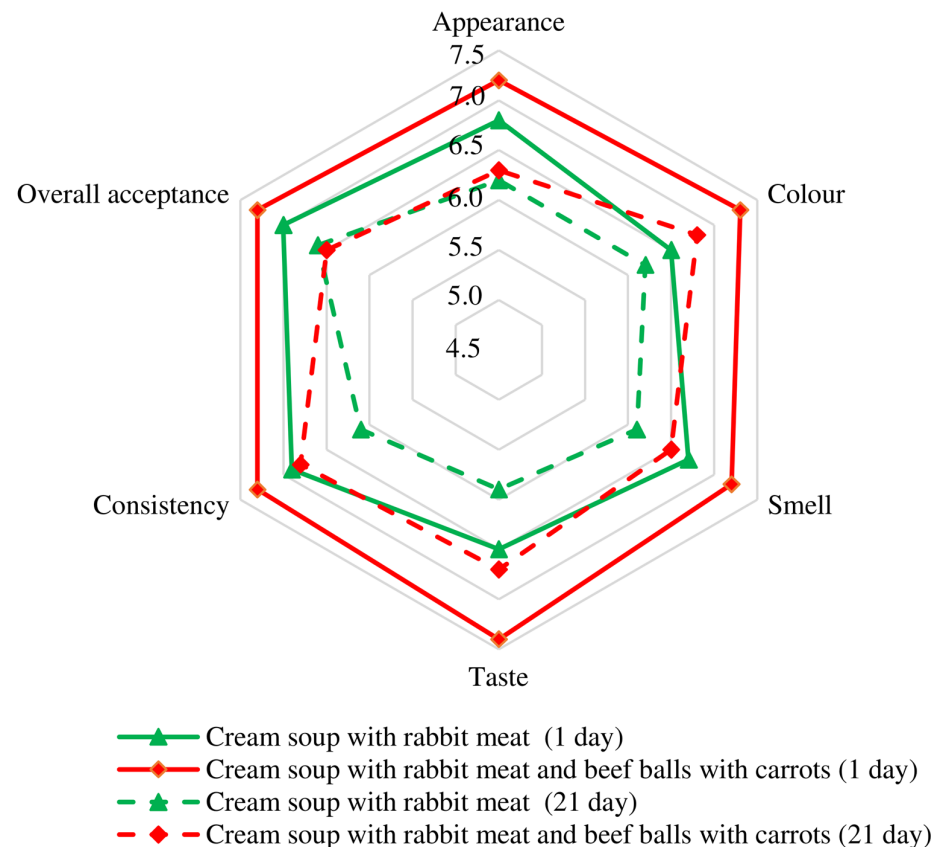
### 3.5. Sensory Analysis

The hedonic quality assessment resulted in determination of the level of acceptability of the model soups and enabled analysis of individual sensory quality characteristics. As can be seen in Figure 9, the evaluators found the vegetable cream soup with beef balls to be more acceptable as it received higher ratings for its sensory characteristics.

On the first day of the study, all characteristics of the cream soup with beef balls and carrots were rated higher by the representatives of the target group. The taste and appearance were rated as average (contingency coefficient values of 0.46 and 0.43, respectively). The consistency of the model soup with beef balls and carrots was rated higher. The contingency coefficient value of 0.33 indicated a weak correlation.

Presumably, the beef balls increased the taste and aroma profile of the product due to the specific taste characteristics of beef. The beef balls also increased the attractiveness of the model soup. The evaluators found the soup with beef balls to be more attractive and more varied. They rated its colour better, probably because the beef juices (including colouring agents) partly penetrated the soup during heating. As the evaluators found the soup consistency acceptable, it can be concluded that elderly people will not have problems biting or swallowing beef balls. This fact was also confirmed by the low values of the texture parameters, which were determined instrumentally.

The results of the semi-consumer evaluations made for two storage periods (1 and 21 days) enabled verification of the level of acceptability of the innovative soups within the assumed shelf life. There were similar values for the individual sensory quality characteristics of the model soups in both storage periods. The differences were not statistically significant ( $p > 0.05$ ). The only exception was the overall appearance of the model soups. There were statistically significant relationships between the storage time and the rating of the overall appearance. Although there were no statistical differences, the evaluators preferred the cream soup with beef balls to the vegetable cream soup in both storage periods. As can be seen in Figure 9, the quality characteristics of the innovative soups in the last storage period point to positive reception of the products by future consumers.



**Figure 9.** The preference ratings of the target group of consumers of the model soups on the first and 21st day of storage.

Soups need to have a moderate liquid consistency to be acceptable to consumers. Starch-based thickeners are usually used in the soup production process because they are readily available. The ideal soup should be thick enough. It cannot be watery or lose the desired viscosity when stirred. The most favourable sensory parameters apply to a soup that falls within the scope of consumers' general perception or acceptance. In other words, such a soup cannot receive lower sensory ratings for its aroma, taste, creaminess, consistency, and overall acceptability [44].

### 3.6. Microbiological Analysis

As the company manufacturing the model meat products uses a specific confidential hurdle technology in the food safety and quality assurance systems, no microbiological analysis was included in this study.

It is important to note that not only the nutritional value, texture, and sensory properties but also microbiological safety should be taken into consideration when soup with added vegetable products is manufactured. There is little information available on the microbiological quality of vegetable and meat cream soups. They mainly concern instant vegetable soups [45,46] and powdered soups prepared from different fish species [47,48]. The model soups (the vegetable cream soup with rabbit meat and vegetable cream soup with rabbit meat, beef balls, and carrots) were safe for consumers' health due to the low content of microorganisms. In the last period of the assumed shelf life, the total count of mesophilic microorganisms was  $<4.0 \times 10^1$  cfu/g, the count of mesophilic lactic acid bacteria was  $<4.0 \times 10^1$  cfu/g, and the count of *Listeria monocytogenes* bacteria was  $<1.0 \times 10^1$  cfu/g. There were no *Salmonella* spp. bacteria in 25 g of the soup.

Farzana et al. [49] analysed the microbial load of the vegetable soup powder during 9 months of storage. According to Food Standards Australia New Zealand, the total aerobic plate count, total yeast, and mould count were within the acceptable limits, whereas no

coliform or *E. coli* was found for up to 6 months. After 6 months, the hygienic indicator organisms were gradually increased, and the product quality began deteriorating.

#### 4. Conclusions

Food for elderly consumers should meet their specific nutritional needs and meet sensory and structural expectations. The ready-made meals presented in our study were characterised by diversified quantities and types of meat and vegetables as well as lower salt and fat contents. Apart from that, they had low sugar contents and no stabilisers, flavour enhancers, colouring agents, or acidity regulators. The homogeneous cream soups had quite similar textural properties. The analysis of the rheomechanical parameters of the soups showed that they had relatively high densities and, consequently, viscosities, which was better perceived by the elderly consumers. The cream soup with beef balls and carrots was characterised by slightly better sensory characteristics and desirability and a higher overall protein content. Importantly, the soup products were microbiologically safe for consumption. The recommended limit of the count of bacteria was not exceeded in either of the soup samples. The results of our study will be used to prepare innovative recipes for vegetable cream soups with rabbit meat and with beef balls and carrots to implement the procedure of their industrial production.

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