The Annals of the University Dunarea de Jos of Galati
Fascicle VI – Food Technology (2018), 42(1), 61-76

ORIGINAL RESEARCH PAPER

INSTRUMENTAL AND SENSORIAL TESTS FOR PREDICTING THE TEXTURAL PROFILE OF REFORMULATED MEATLOAF

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Received on 18th September 2017
Revised on 9th February 2018

The aim of this research was to evaluate and compare the textural properties of four types of reformulated meatloaf. Textural characteristics were investigated using three instrumental tests (Texture Profile Analysis, Wire Cutting and Volodkevich Bite) and two sensorial methods (Acceptance Testing and Texture Profile Method). The meatloaf samples were reformulated by replacing one part of the pork backfat with emulsions containing powder milk, walnuts and different vegetable oils. When comparing the results of the instrumental and sensorial analysis, values between 0.84 and 0.96 for correlation coefficients were obtained. The partial substitution of fat in the reformulated meatloafs significanly influenced the textural parameters of sample.

Keywords: meatloaf, milk powder, sea buckthorn oil, sunflower oil, textural analysis, walnuts

Introduction

Nowadays, an important trend has emerged in promoting healthy and dietary foods. The studies on consumer behaviour show that meat consumption is being more and more influenced by nutritional considerations (Angulo and Gil, 2007; Sousa *et al.*, 2017). Meat represents an essential component of a well balanced diet owing to its properties as a source of high-quality protein, high-available iron and B-group vitamins (Biesalski, 2005; Arihara, 2006; McNeill and Van Elswyk, 2012).

One of the meat components is fat, which plays an important role in meat products processing reducing cooking loss, improving water holding capacity and providing flavor, juiciness and desirable mouthfeel (Carballo *et al.*, 1995; Muguerza *et al.*, 2002). On the other hand, the high animal fat intake is frequently associated with obesity, hypertension, cardiovascular diseases and coronary heart diseases (Luruena-Martinez *et al.*, 2004; Moon *et al.*, 2008; Ozvural and Vural, 2008).

Although meat is nowadays considered as a controversial food, the nutritional quality of processed meat products have to regain consumer trust. Consumers who suffer from coronary problems and other associated diseases are advised to choose low fat or low saturated fat food/meat products in an attempt to reduce risk factors. To respond to the consumers demand, meat products were reformulated by partial or complete replacement of fat with vegetable oils (Cáceres *et al.*, 2008; Álvarez *et al.*, 2011; Morais *et al.*, 2013; Mora – Gallego *et al.*, 2013) and/or with walnuts (Cofrades *et al.*, 2008; Olmedilla-Alonso *et al.*, 2008; Álvarez *et al.*, 2011). It is well known, that regular consumption of 43 g/day of walnuts is beneficial for the prevention of coronary heart disease (FDA, 2004). The study of Ayo *et al.,* (2008) evidenced the presence of several bioactive compounds in frankfurters with added walnuts, this improving the potential functional character of meat products that may reduce the risk of heart disease.

Several studies reported the use of sea buckthorn oil as a natural antioxidant in meat systems like mechanically deboned chicken meat, mechanically deboned turkey meat and salami (Pussa *et al*., 2008; Mihociu *et al.,* 2014; Kumar *et al*., 2015).

It is well known that dairy products are used nowadays to improve the functional properties of meat products. These ingredients are used in meat products to improve the textural and sensorial properties and to reduce cooking losses (Hung and Zayas, 1992; Barbut, 2010). Milk proteins have specific properties related to immobilization of water, texture and consistency control, with implications in color improvement and enhancement of sensory attributes (Ulu, 2004; Andiç *et al.*, 2010).

The rheological behaviour of the food products, including the textural feature, may be studied by several mechanical methods such as compression, torsion, tension or shear. Many instrumental methods have been developed by several researchers in order to determine food textural properties (Bourne, 2002; Kilcast, 2004; Yang *et al*., 2010; Choe *et al*., 2013; Henning *et al*., 2016).

Texture profile analysis (TPA) is widely used as an instrumental method for food texture analysis, due to the fact that it simulates the conditions in which the material is subjected to the entire mastication process (Bourne, 2002). The compression parameters obtained with TPA were used by many authors to evaluate texture characteristics of meat products (Bruna *et al.,* 2000; Hoz *et al.,* 2004; Visessanguan *et al.,* 2004; Houben *et al.,* 2005). However, there are only a few studies concerning the Wire Cutting (Goh *et al*., 2005) and Bite Tests of meat products. These three methods of texture analysis were used in order to establish a general behaviour of meat products during preparation for consumption (Wire Cutting) and consumption itself (biting and mastication).

Moreover, to the best of our knowledge, there are little data in the scientific literature aproaching aspects related to the comparison of many instrumental tests for assesing food texture (Breuil and Meullenet, 2001). Within this context, the study aimed to evaluate and to compare the textural properties of four types of reformulated meatloaf. The meatloaf samples were tested by Texture Profile Analysis (TPA), Wire Cutting (W) and Volodkevich Bite (VB) in order to evaluate the effect of animal fat replacement with emulsions of milk powder and different oils together with walnuts addition on the sensorial properties of reformulated meatloaf.

The instrumental analysis of food texture is based on the rheological and mechanical properties of food. The precision, reduced costs and reduced time are some of the advantages of this type of analysis. Anyway, the mechanisms of food mechanical properties conversion into sensorial textural properties still needs to be investigated. According to Foegeding *et al.*, (2011), the human perception of any product is best measured by humans, not machines. This is owed to the complex relationships between the food properties (including physical characteristics, mastication and swallowing behavior) and the mechanisms implied in human perception (mastication, oral processing). Consequently, the sensory analysis was applied in order to get a complete image of meatloaf texture.

Materials and methods

Materials

The fresh pork pulp (moisture 72.87%, fat 4.86%, protein 20.92%) and pork backfat (moisture 12.73%, fat 85.74%) were bought from a local processor at no more than 48 h postmortem. Sea buckthorn oil was provided by S.C. Hofigal Export Import S.A. Bucharest, Romania. All the other components (sunflower oil, walnut oil, walnuts, milk powder, sodium chloride and pepper) were purchased from a local supermarket in Galati (Romania).

Preparation of samples

The fresh pork pulp was chopped with a kitchen block Philips Essence HR7766 from EC, the walnuts were also grounded (for approximately 2 min). Four different meatloaf were prepared using the formulations given in Table 1. The control sample contained 23% pork backfat. The other three meatloave samples were prepared with added walnuts, vegetable oils and powder milk.

Table 1. Formulation (g) of experimental products

Sample*	**Fresh pork pulp**	**Pork backfat**	**Walnuts**	**Vegetable oil****			**Powder milk**	**Salt**	**Pepper**	**Water**
				SFO	SBO	WNO				
C	175	57.5	–	–	–	–	–	1.25	0.25	16
MSF	175	42.5	11.5	3.5	–	–	11	1.25	0.25	5
MSB	175	42.5	11.5	–	3.5	–	11	1.25	0.25	5
MSN	175	42.5	11.5	–	–	3.5	11	1.25	0.25	5

*C – Control meatloaf; MSF – meatloaf with walnuts and sunflower oil emulsion; MSB – meatloaf with walnuts and sea buckthorn oil emulsion; MSN – meatloaf with walnuts and walnut oil emulsion.
**Vegetable oil: SFO – sunflower oil; SBO – sea buckthorn oil; WNO – walnut oil.

The walnuts were incorporated in the meatloaf mixture with an emulsion of milk powder, water and different types of vegetable oils. The meatloaf samples were put in aluminum special trays for cooking. The cooking process was carried out in a Sharp R – 94 ST convection oven (Germany) at 180°C for 50 minutes. To provide the optimal characteristics of cooking process, the oven has preheated for 10 minutes (Akwetey *et al.*, 2014). In these conditions, the core temperature of the samples reached values between 74 and 80°C. After cooking, the samples were brought to room temperature and kept in the refrigerator for 24 hours. Before testing, the meatloaf samples were brought to the room temperature (25°C). The proximate composition and cooking loss for all the samples was discussed by Mocanu *et al*., (2015).

The moisture content of meatloaves ranged from 62.34 ± 0.38 g/100g (C) to 58.83 ± 0.21 g/100g (MSF). The protein content was higher for meatloaf with sea buckthorn oil and walnuts emulsion (18.35 ± 0.18 g/100g) than the control sample (13.69 ± 0.16 g/100g). The fat content of meatloaf sample containing only animal fat was higher (23.15 ± 0.25 g/100g) than the samples formulated with vegetable oil and walnuts (20.62 ± 0.19 g/100g), with the lowest value in the sample MSB. The cooking loss for all the meatloaves ranged between 10.16% for MSF sample and 12.97% for C sample (Mocanu *et al*., 2015).

Texture analysis

All the textural analyses were performed at room temperature with a Texture Analyzer CT3 (Brookfield, UK). The Texture Analyzer CT3 it is provided with a wide range of probes used to every instrumental test in the present work. The parameters used to predict the textural profile of meatloves were hardness (N), fracturability (N), cohesiveness (dimensionless), springiness (mm), gumminess (N), chewiness index (N). Due to the fact that the cutting and the shaping are dependent by the type of the instrumental test applied, for each test, samples were cut differently according to the used probes dimensions.

Texture Profile Analysis (TPA): For TPA, a 25.4 mm diameter acrylic cylinder was used. The samples were cut in cylindrical pieces, with a length of 10 mm and a diameter of 12 mm, then they were double compressed to half of their initial height, using a compressing speed of 2.0 mm/s and a loading cell of 1 kg.

Wire Cutting (W): The Wire Cutting tests were performed with the Wire Cutting probe of the texture analyzer (wire length 40 mm and 0.3 mm diameter). The samples were cut in cubic shape with a side of 20 mm at a test speed of 1 mm/s.

Volodkevich Bite (VB): Regarding the biting tests, the "*Volodkevich bite jaws*" probe encoded TA-VBJ, which penetrates the samples at 7 mm, was used. It consists of both the upper jaw and lower jaw, imitating human bite. It can be described as simulating the action of shearing by the front incisors, when they bite the food, generating an indication of the sample hardness and fracturability. The samples were cylinders with a length of 20 mm and a diameter of 0.9 mm with a test speed of 1 mm/s.

All the textural tests were done two times for each sample and the average values together with standard deviation were reported.

Sensory evaluation

Two methods were used for the sensory analysis of meatloaves, the first - Acceptance Testing concerning the three general sensorial attributes (acceptance, colour and taste) was applied after the method of Akwetey *et al.* (2014) and the second one - Texture Profile Method regarding the main textural characteristics presented by Lawless and Heymann (2010).

The Acceptance Testing was performed using a hedonic scale of 9 points (1 represents dislike extremely, while 9 represents like extremely). The products were sliced to approximately equal sizes of 2.0 cm^2, wrapped in kitchen foil and warmed in an oven until the meatloaf temperature reached 25°C. All products were blind coded with 3-digit random numbers and the orders of serving all meatloaf samples were randomized. The sensorial test was carried out in individual booths using fluorescent lamps (simulating daylight). Water was offered to rinse the mouth between tasting the meatloaves samples in order to distinguish clearly the specific flavours.

Samples evaluation was performed by 15 untrained panellists in the age range 20–25 years. The main criterion for the panellists' choice was "regular consumption of meat products". The consumers were asked to evaluate the meatloaves using the following descriptors: appearance (this refers to shape, size, homogeneity, cross section aspect (Hutchings, 1999)), colour, taste.

Texture Profile Method involved 15 trained panellists. Three training sessions were organised in order to familiarize the tasters with the products and terminologies of meatloaves.

Hardness (the force necessary to bite entirely through sample placed among molars), springiness (the force with which the sample returns to its original size/shape, after partial compression between the tongue and palate), cohesiveness (the amount of deformation undergone by the material before rupture when biting completely through the sample with molars), gumminess (the amount of manipulation necessary before the food disintegrates), chewiness (the numbers of chews required to reduce the sample to a state ready for swallowing) were evaluated by the trained panelists (Stone and Sidel, 1992). The main descriptors which are related to the texture profile of meatloaves were especially pursued.

Statistical analysis

One-way analysis of variance (ANOVA) was carried out on the experimental results. Differences were considered significant at $p < 0.05$. All results were presented as mean value ± standard error. Statistical processing of the data was performed using free trial of the program STATGRAPHICS Centurion XVI Version 16.1.11. To determine the relationship between data obtained for TPA, Wire Cutting and Volodkevich Bite it was used a Durbin-Watson statistic test by means of DataFit 9.1.32 – free trial.

Results and discussion

Texture profile analysis (TPA)

The TPA test consists in a double compresion of the sample, imitating the mastication process. For TPA, six main textural characteristics: hardness (the maximum force required to compress the sample in the first compression cycle), fracturability (originally known as brittleness) was defined as the force of the significant break in the curve on the first bite, cohesiveness (extent to which the sample could be deformed prior to rupture), springiness (the ability of sample to recover its original form after the deforming force is removed), gumminess (the force needed to disintegrate a semisolid sample to a steady state of swallowing, hardness × cohesiveness) and chewiness index (the work needed to chew a solid sample to a steady state of swallowing, springiness × gumminess) were tested. They were defined by Bourne (2002); Martinez *et al.*, (2004); De Huidobro *et al.*, (2005); Wu *et al.*, (2006); Kealy (2006); Jaworska and Bernas (2010); and Guine and Barrocab (2012).

In Figure 1, the TPA characteristics of the studied samples of reformulated meatloaf are presented.

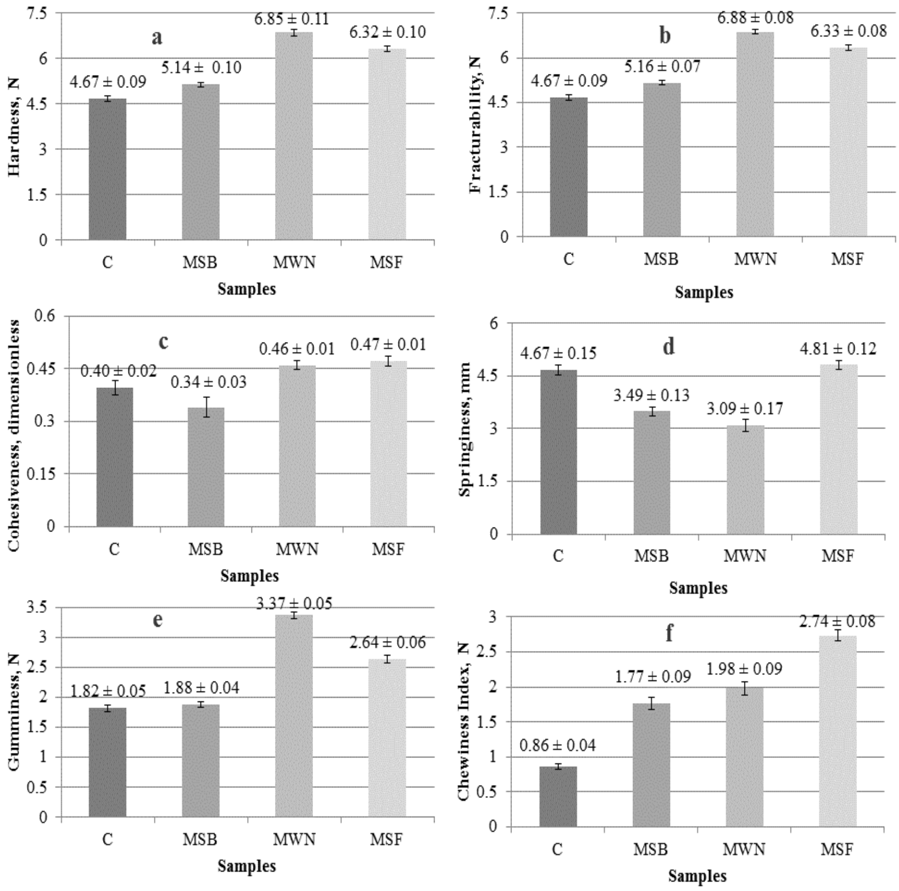

Figure 1. TPA characteristics of the studied reformulated meatloaf samples

From Figure 1. a, b, e, it can be observed that the addition of the emulsion of milk powder, water and walnut oil (sample MWN) resulted in several significant changes in the textural parameters. Thereby, the hardness, fracturability and gumminess reported the highest values for MWN in comparison with the other samples. Especially, the values for hardness and fracturability were almost 47% higher than that of the values for the control sample, while the gumminess values for MWN registered a significant increasing value of 85% in comparison to control sample.

It is expected that gumminess would have a high value because of its direct dependency on hardness and cohesiveness. Similar results were also reported by other researchers like Vossen *et al.*, (2012) for porcine frankfurters with dog rose added and by Youssef and Barbut (2011) for meat products from beef with pre-emulsified canola oil.

However, some different trends in springiness (Figure 1-d) and chewiness index (Figure 1-f) values were oberved. Thus, the value for springiness parameter decreased by 33% in comparison to the control sample. The chewiness index value was lower than that for MSF (meatloaf with walnuts and sunflower oil), but about 1.3 times higher than the control sample. Thus, the hardness highest value indicated a compact texture of MWN specific to meatloaf, but it also presented a significantly harder chewing than the control sample as Ayo *et al.*, (2008) have reported for frankfurters.

MSB sample (meatloaf with walnuts and sea buckthorn oil) presented similar values with the control sample of all the parameters, excepting springiness and chewiness index. Regarding the significant increasing of the chewiness index in the range of 0.86-2.74 N, it can probably be justified by the adding of some external sources of protein, like milk powder and walnuts. This idea is supported also by Claus *et al.*, (1990); Gregg *et al.*, (1993) and Cavestany *et al.*, (1994) who analyzed the effect of reducing the fat content on the texture of meat-based emulsion products, and they reported that as long as the meat protein content is maintained constant, the product is softer.

Wire Cutting test

A similar batch of samples identically by composition of meatloaf with walnuts and different emulsions of milk powder were tested. Three different emulsions based on powder milk reconstituted in water at 40°C, walnuts and vegetable oils were used. In the first one, sea buckthorn oil, was added; in the second, walnut oil; and in the third, sunflower oil. The same textural parameters were also investigated. The results of Wire Cutting test are presented in Table 2.

The main differences were established for fracturability and for hardness. The samples in which the pork backfat was replaced with walnuts and vegetal oils emulsions registered approximative 1.5 times higher fracturability values comparing with the control sample. An increasing by approximative 1.4 times was also registered for the values of hardness.

As the values of fracturability and hardness do not significantly differ between the samples with vegetal oils addition, it can be concluded that these two textural parameters were influenced by the reduction of the pork backfat content.

Table 2. Textural parameters of reformulated meatloaf samples determined by Wire Cutting test

Textural parameters	***Sample***			
	C	**MSB**	**MWN**	**MSF**
Hardness (N)	3.14 ± 0.27	4.81 ± 0.17	4.60 ± 0.25	4.49 ± 0.19
Springiness (mm)	3.95 ± 0.18	4.04 ± 0.13	5.57 ± 0.25	5.63 ± 0.19
Fracturability (N)	2.85 ± 0.13	4.74 ± 0.27	4.54 ± 0.22	4.51 ± 0.13
Chewiness Index (N)	0.69 ± 0.09	0.38 ± 0.04	0.69 ± 0.02	0.42 ± 0.08
Gumminess (N)	0.72 ± 0.14	0.88 ± 0.14	0.79 ± 0.12	0.88 ± 0.11
Cohesiveness	0.25 ± 0.05	0.22 ± 0.02	0.27 ± 0.03	0.21 ± 0.04

All values are mean ± standard deviation of two replicates

The compact texture of meatloaf samples may be due to the powder milk used for the emulsions obtaining. Values registered for the rest of the textural parameters determined by Wire Cutting Tests were not significantly different, suggesting that this test has not the same accuracy as the Texture Profile Analysis in the case of meatloaf.

Volodkevich Bite test

This test provided some important information especially for hardness and fracturability, which are specific to the action of shearing by the human front incisors.

From Figure 2, it can be observed that for the bite test, the highest values of the textural parameters were registered for MSF (meatloaf with walnuts and sunflower oil). MSF has reported an increase in hardness (Figure 2-a) value ranging from the control sample value 1.33 ± 0.07 N to 3.08 ± 0.07 N.

The fracturability (Figure 2-b), chewiness index (Figure 2-f) and gumminess (Figure 2-e) registered the most increased value of all the samples. Compared to the other two types of solicitations, MSF showed to be the most compact sample. For all the samples, the values for hardness were similar and in perfect accordance with those for fracturability, the results indicating the importance and the dependence of both parameters, as it was mentioned before. Springiness values have an insignificant variance for all the meatloaf samples. Cohesiveness seemed to be influenced by the animal fat presence, while the highest values (0.27 ± 0.04) were registered for the control sample.

Taking into consideration the results of the instrumental analysis, it may be concluded that the partly replacing of backfat with vegetal oil emulsions leads to an enhanced texture of meatloaves. These results can be correlated with the proximate composition of the samples after cooking, presented in a previousstudy (Mocanu *et al*., 2015). This can be explained by the protein properties which are forming irreversible gels by restructuring into three-dimensional networks and it entraps water within the capillaries of the gel matrix. Barbut (2010) reported that milk proteins increased the TPA parameters for cooked lean chicken meat batters and had a positive role in co-gelling with the meat proteins.

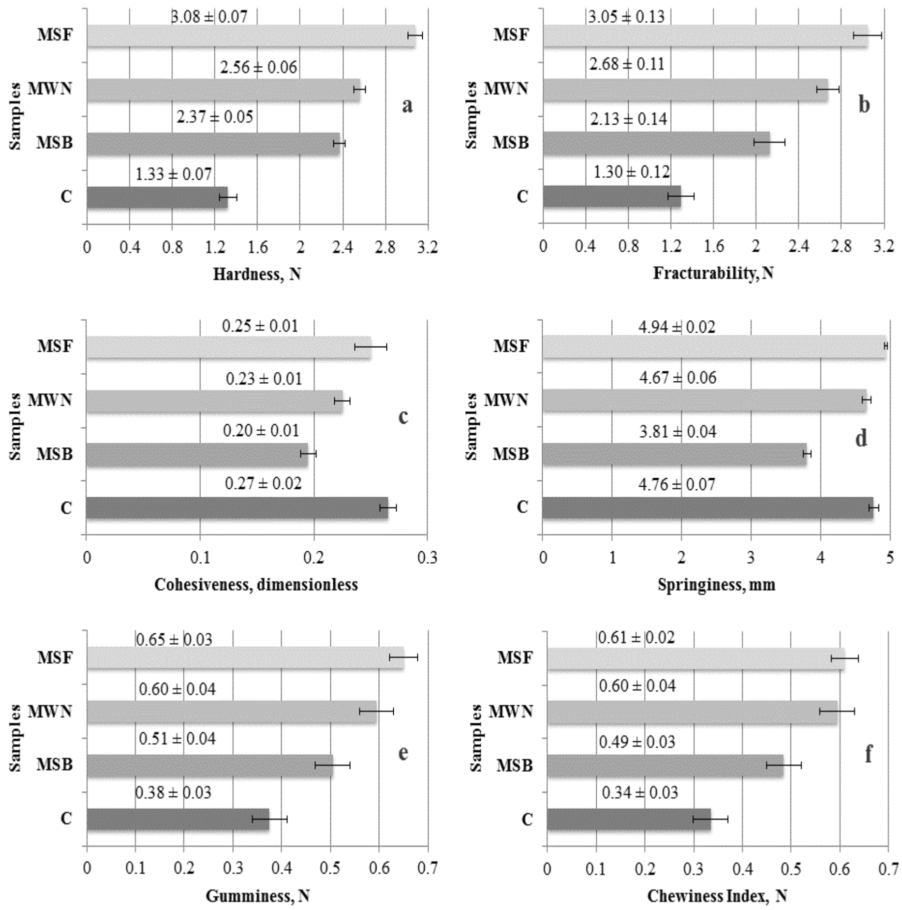

Figure 2. Bite test characteristics of the studied samples of reformulated meatloaf

Sensory analysis

The sensory evaluation of the meatloaves is shown in Figure 3 and Figure 4. Each reduced-fat meatloaf sample was evaluated for appearance, colour, taste, hardness, springiness, cohesiveness, gumminess and chewiness. The last five descriptors were tested as well as to find the correlation between the textural profile techniques and the human acceptability. The mean scores for color ranged from 5.37 (C) to 8.8 (MSB). The MSB sample presents the highest color scores ($p < 0.05$). These results may be due to the presence of sea buckthorn oil whose color is orange. So the colour is improved by the sea buckthorn oil usage, with a clear potential for natural meat products coloring. The sensorial analysis of the colour showed a better visual appearance for all the samples with reduced backfat; this may be explained by the antioxidant effect of the compounds present in vegetal oils and walnuts (Mocanu *et al.*, 2015), which prevented the myoglobin oxidation (Nieto *et al.*, 2017). The control sample registered the lowest score for taste and appearance.

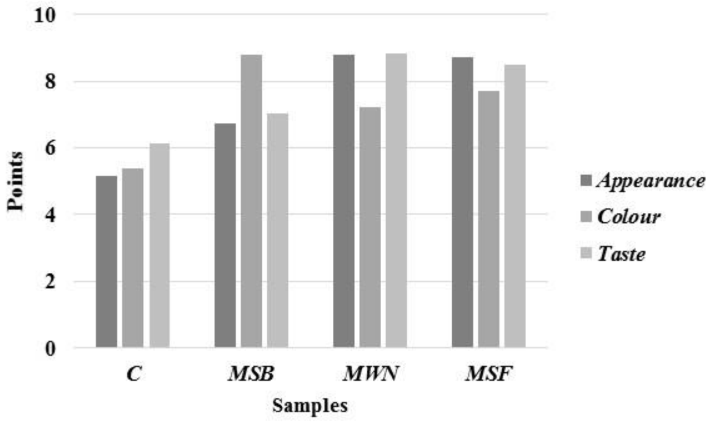

Figure 3. Comparative analysis of sensory profile of meatloaves for appearance, colour and taste – *Acceptance Testing*

Figure 4 highlights that the walnuts and sea buckthorn oil adding increased the general scores for hardness, springiness, cohesiveness and gumminess as compared to the control sample ($p < 0.05$) sensorial results.

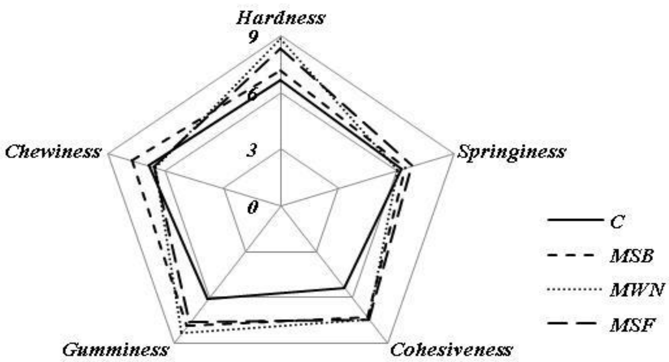

Figure 4. Sensorial analysis of meatloaves for hardness, springiness, cohesiveness, gumminess and chewiness – *Texture Profile Method*

This fact may be due to the high content of polyunsaturated fatty acids from sunflower oil which can influence the textural properties (Rodríguez-Carpena et al., 2011); the authors have found out that the increased cohesiveness in patties with added sunflower oil may be due to the characteristics of sunflower oil (higher PUFA content) and the size fat globules formed during the manufacture process. The same results were obtained by Youssef and Barbut (2011) for burger patties reformulated with vegetable oils with high-PUFA, which increased the cohesiveness of the samples.

In order to find out if the instrumental analysis of texture is relevant for the consumers, the values of textural parameters determined by TPA were correlated with their scores obtained by sensorial analysis. The reason for taking into account the results of TPA was the similarity between mastication and the double compression used by this method.

In Table 3, the R^2 values between instrumental and sensorial analysis are shown. The good correlation between all parameters suggests that, selected instrumental tests and sensorial analysis may be able to use for meatloaves evaluation, the best coefficient (0.9605) being registered for hardness can be noticed.

Table 3. Correlation coefficients for textural parameters determined by TPA and by sensorial analysis

Textural parameter	***Hardness***	***Springiness***	***Cohesiveness***	***Gumminess***	***Chewiness***
R^2	0.9605	0.8449	0.8824	0.9101	0.9165

Statistical analysis

The ANOVA analysis (Table 4) decomposes the variance of the data into two components: a between-group component and a within-group component.

Table 4. The results of statistical analysis (ANOVA) applied to TPA test

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	133.02	5	26.60	10.77	1.34E-07	2.35
Within Groups	162.98	66	2.46			
Total	296	71				

SS – Sum of Squares; df – degrees of freedom; MS – Mean Squares; F – statistic test; P-value – probability.

In order to correlate not only the main textural characteristics, but to compare the same parameters for three different types of solicitation a Durbin–Watson statistic test was used (Table 5).

Durbin–Watson statistic is a test used to detect the presence of autocorrelation (a relationship between values separated from each other by a given time lag) in the residuals (prediction errors) from a regression analysis. It was considered that the six textural characteristics are dependent variables, while the three instrumental tests are independent variables. The value of the Durbin–Watson statistic ranges from 0 to 4. As a general rule of thumb, a value of 2 means that there is no autocorrelation in the sample. A value close to 0 indicates strong positive correlation, while a value of 4 indicates strong negative correlation. Multiple linear regression analysis was performed to determine the differences between all meatloaf samples for each instrumental test used to predict textural profile. The data used for multiple linear regression analysis were the values of textural parameters determined by each instrumental test.

The test reveals that there is a very high correlation between the obtained data arranged by multiple linear regression analysis. Significant coefficients of determination (R^2) for the three instrumental tests were found (Table 5).

Table 5. Multiple linear regression analysis for three instrumental tests

Texture analysis	***R^2***	***SE***	***DW***
Texture Profile Analysis	0.9658	0.773	2.505
Wire Cutting	0.9881	0.455	0.997
Volodkevich Bite	0.9998	0.051	1.311

R^2 = coefficient of determination (correlation coefficient square); SE = standard error of the estimate; DW = Durbin – Watson test.

The values of correlation coefficient for these three instrumental tests ranged from 0.9658 for Texture Profile Analysis of 0.9998 for Volodkevich Bite. The value of Durbin-Watson statistic ranged from 0.997 (Wire Cutting test) to 2.505 for TPA, this proves that there are significant differences between the three types of textural testing. This rheological behaviour seems to be expected while the three instrumental tests involve different actions.

Conclusions

Partial reducing the fat content may have some significant influences especially on the hardness, fracurability and chewiness of the reformulated meatloaf. The results from the present study evaluated the importance of technological applications of sunflower, sea buckthorn and walnut oil as food ingredients added in the meatloaf matrices. Emulsion composition is a highly challenging subject, to improve the quality of reformulated meatloaf, so it is still important to develop other types of emulsions.

The textural characteristics of the samples with added vegetable oils and walnuts registered various scores. The MSB sample was mentioned as most appreciated by panellists. A possible explanation of this choice may be a more pleasant visual appearance of MSB sample and a low resistance to mastication.

The textural and sensorial results correlations were very tight, so the reformulated samples recorded similar scores for hardness, chewiness and gumminess. This aspect can justify a high general acceptability of the panellists. However, further studies are required for better understanding of texture profile and sensorial analysis correlation using other types of matrices.

Acknowledgments

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/132397.

This work was supported by the NURC-UEFISCDI Romania as National Project II no. 115/2012 – OPTIMEAT.

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