Functional and technological characteristics of semi-finished products with shell of dough

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Keywords:

Semi-finished product
Meat
Freezing
Hemp
Seed
Protein

Article history:

Received 10.07.2023
Received in revised form 16.11.2023
Accepted 19.12.2023

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DOI: 10.24263/2310-1008-2023-11-2-3

Abstract

Introduction. The aim of the present research was to study the functional and technological properties of semi-finished products with a shell of dough prepared from chicken meat with incorporation of hemp seed flour or hemp protein together with corn starch hydrated by electrochemically activated water.

Materials and methods. White meat of broiler chickens, corn starch, and hemp seed flour and hemp seed protein were used as main raw materials for the production of dumplings. Drinking water, anolyte, or catholyte were used to hydrate the dry ingredients. Moisture content, water activity, pH value, water binding capacity, emulsifying ability of fresh and defrosted dumplings were determined. Thermographic analysis of defrosted dumplings was performed.

Results and discussion. Eight formulations of dumpling fillings based on application of combination of chicken meat with helm processing products and corn starch were studied to find improved composition, which ensured high technological characteristics of the final product. All samples had the moisture content above 60%, which is a sufficient value for this type of product. The samples with corn starch, activated water and hemp seed protein had increased moisture by 3.6–8.0% and with hemp flour by 8.6–18.3 % compared to the corresponding control samples. After defrosting, all samples showed a decrease of moisture content, but this moisture loss was smaller in experimental samples added with corn starch than in control samples without it. Fillings with higher content of corn starch showed lower moisture loss. It was confirmed for dumpling fillings, as well as for dumplings themselves. Water-binding capacity (WBCw) of the control increased significantly after defrosting compared to the values before freezing. However, the values of the WBCw for the dumpling fillings with corn starch and activated water remained unchanged after thermal exposure. The dumplings prepared with addition of hemp seed flour or hemp protein had water activity values, a_w, in the range from 0.955 to 0.971. Dumplings containing hemp protein and corn starch had lower a_w values compared to correspondent control. On the contrary, dumplings with hemp flour and corn starch had higher a_w values than correspondent control. Comparison of the samples with electrochemically activated water, showed that lower a_w values were found for the fillings prepared with anolyte. The results of thermographic analysis show that the use of catholite in the samples makes it possible to obtain thermally stable systems to high temperatures.

Conclusion. Combination of hemp seed and corn starch processing products with different hydration methods allows to obtain semi-finished products with high functional and technological indicators.

Introduction

The use of plant materials in the manufacturing of food products, and in particular meat products, is a new rapidly developing direction in the modern food industry. Plant materials attract the attention of research because they contain proteins, dietary fiber, vitamins, antioxidants, and their addition to traditional foods makes it possible to create functional products that have new qualities and meet the requirements of various groups of the planet's population (Ivanov et al., 2021; Stabnikova et al., 2021). For example, it was proposed to use chia (*Salvia hispanica* L.) flour and chia seeds for partial replacement of fat in burgers, hamburgers, frankfurters, and ham-like products. This replacement allows to decrease the content of fat, increase the content of fiber and omega-3 polyunsaturated fatty acids, improve ratio of omega-6 to omega-3 essential fatty acids, and extend the shelf life of meat products (Stabnikova and Paredes-Lopez, 2024). A number of studies in recent years have been devoted to the use of hemp (*Cannabis sativa* L.) processing products to create a variety of functional foods including gluten-free bakery products (Nissen et al., 2020; Yano and Fu, 2023), hemp seed milk made by homogenizing ground seeds in water (Wang et al., 2018), and meat products (Bozko et al., 2021; Zając et al., 2019).

The nutritional and biological values of hemp seed processing products vary depending on the region and method of hemp cultivation, but in any case remain high (Irakli et al., 2019; Oseyko et al., 2021). Analysis of different literature sources showed that hemp seeds contain, mg/100 g: moisture, 1.1–9.2; protein, 21.3–25.6; fat, 24.5–35.9; carbohydrates, 27.6–38.1; total dietary fiber, 27.6–33.8; insoluble dietary fiber, 22.2–30.9; ash, 3.7–5.9. Helm seeds are rich in linoleic acid (omega-6) and alpha-linolenic acid (omega-3), having a healthy food preferred ratio 3:1 for ω-6/ω-3 (Rupasinghe et al., 2020). Besides that, hemp seeds are rich in phenolic compounds, tocopherols, carotenoids and demonstrate antioxidant activity (Farinon et al., 2020). Hemp seed processing products, such as hemp seed flour and hemp protein, produced from defatted hemp cakes, a residue of hemp seed oil extraction, are good ingredients for functional food manufacturing (Mamone et al., 2019).

Flour from hemp seeds has high content of protein, 33% (w/w), low content of fat, 4.5% (w/w), and good profile of fatty acids, where polyunsaturated fatty acids consist 38% (w/w), including α-linolenic acid (omega-3), 8% (w/w) and linoleic acid (omega-6), 27% (w/w). Additionally, hemp seed flour is free of cholesterol, contains dietary fibers, 4% (w/w), polyphenols, flavonoids, tocopherols, terpenes, and possesses antioxidant activity (Nissen et al., 2020). Proteins of hemp seeds contain all essential amino acids and the most abundant amino acids are glutamic acid (3.74–4.58% of whole seed) and arginine (2.28–3.10% of whole seed) (Farinon et al., 2020).

Introduction of plant materials into recipes of meat products is a very popular way to increase their nutritional and biological values (Hinderink et al., 2021; Schreuders et al., 2021; Zhang et al., 2021). However, the application of plant protein as meat analogs could affect the technological and sensory properties of the final product (Boukid, 2021; Cordelle et al., 2022).

It is possible to increase the nutritional value of meat products while maintaining high technological parameters in case when application of hemp seed products is accompanied with addition of corn starch. Corn starch is commonly used as a structuring agent and a substitute for the part of fat in meat products to improve fatty acid profile, decrease lipid oxidation and microbiological count, especially in the case of frozen storage (Eshag Osman et al., 2021, 2022; Romero et al., 2019; Sá Júnior et al., 2021).

The addition of ingredients in powder form, such as corn starch, hemp seed flour and hemp protein, to minced meat is proceeded by the stage of their hydration. During the hydration, proteins swell to form a viscoplastic mass. The course of this process depends on the properties of the water used for hydration. Electrochemical water treatment could be used to convert water into a metastable excited state. In the process of electrolysis, the catholyte receives a negative potential, the anolyte receives a positive potential because it accumulates near the positive electrode, the anode. According to studies (Marynin et al., 2023), hydration of corn starch with electrochemically activated water allows to produce pates with high rheological properties.

The aim of the present research was study of the functional and technological properties of semi-finished products with a shell of dough prepared from chicken meat with incorporation of hemp seed flour or protein together with corn starch hydrated by electrochemically activated water.

Materials and methods

Materials

White meat of broiler chickens, corn starch, hemp seed flour and hemp seed protein were used as main raw materials for the production of dumplings. Corn starch was produced by AS Group LLC, Kyiv. Flour and seed protein from hemp (*Cannabis Sativa* L.) were manufacturing by Desnaland LLC, Sumy region (Bozko et al., 2021) (Table 1, Figure 1).

Table 1

Characteristics of helm products

Compounds	Hemp seed flour	Hemp protein
Moisture, %	less than 7.0	6.5–7.0
Protein, %	more than 40.0	more than 50.0
Oil, %	less than 16.0	less than 12.0
Ash, %	less than 10.0	less than 10.0
Fiber, %	less than 7.0	less than 15.0

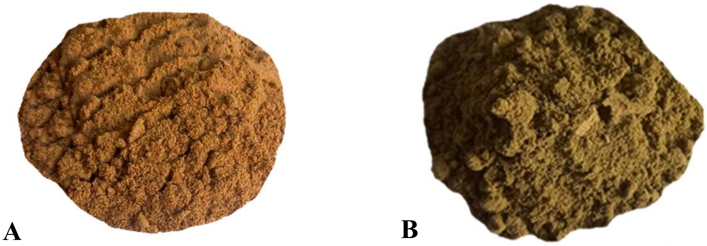

Figure 1. Images of hemp seed flour (A) and hemp protein (B)

Electrochemically activated water: catholyte (obtained by passing a direct electric current through water in the cathode chamber of an electrolyzer) and anolyte (obtained in the process of water oxidation reactions on the anode) (Marynin et al., 2023) was used for hydration (hydromodule 1:2) of hemp products and corn starch instead of drinking water, which was used in control.

Formulations for dumpling fillings are shown in Table 2.

Table 2

Formulations for dumpling fillings

Material	Control		Samples on anolyte				Samples on catholite			
	1	2	1	2	3	4	5	6	7	8
White meat of broiler chickens,%	74	74	74	74	74	74	74	74	74	74
Hemp protein, hydrated 1:2, %	20	-	14	5	-	-	14	5	-	-
Hemp seed flour, hydrated 1:2, %	-	20	-	-	14	5	-	-	14	5
Corn starch hydrated 1:2, %	-	-	6	15	6	15	6	15	6	15
Onion, %	6	6	6	6	6	6	6	6	6	6

Hydrated helm protein was added in control 1, and meat samples 1, 2, 3, and 4; hydrated helm flour was added in control 2, and meat samples 5, 6, 7, and 8. Onion, 6 %, and spices (salt, 1.7 % and black pepper, 0.6%), were added to each minced meat filling.

Dough composition included, %: wheat flour, 58; chicken eggs, 8; water, 34. Drinking water, catholyte or anolyte were used in dough corresponding to water used for filling preparation.

Dumpling preparation

Broiler chicken meat was ground using a meat grinder (HKN-22SS). Hydration of hemp seed and corn starch was carried out with warm (35–40 °C) drinking water, anolyte pH (5.9) or catholyte (pH 9.7) for 15 minutes, hydro module– 1:2. All ingredients were added to minced meat according to corresponding formulation, and the resulting mixture was kneaded using a mixer (Kenwood KVL8470S). The dough was kneaded using a food processor (Kenwood KVL8470S), and activated water or drinking water was used to prepare the dough. The dumplings were formed using a manual mold. The semi-finished products were frozen using a shock freezer (ASH05K) at a temperature of minus 34-35°C until the dumplings reached a temperature of minus 18°C. Frozen dumplings were stored for 14 days, then they were defrosted and analysed.

Methods

The following parameters were determined in the samples: moisture content, water-binding capacity, water activity, pH, emulsifying ability, and plasticity (Bozko et al., 2021).

Moisture content (W, %) was determined by a thermogravimetric method by drying of the sample to a constant weight at a temperature of 105°C. The moisture content was calculated using the formula:

$$W = (m_1-m_2)/(m_1-m), \quad (1)$$

where m is a weight of dry container, g;

m_1 is a weight of dry container with sample before drying, g;

m_2 is a weight of container and sample after drying, g.

Water activity (a_w) was measured at 25°C using a HygroLab 2 analyzer with an accuracy of ±0.01 a_w.

pH value was determined using digital pH-meter pH-150MI. To determine pH in minced meat or dough, a sample weighing (5.00±0.02) g was placed into a chemical beaker with a volume of 250 ml. Distilled water, 50 ml, was added and the mixture was stirring for 30 minutes, then it was filtrated through a filter paper, and filtrate was used for pH measurement.

Water-binding capacity (WBC_w, %), the mass fraction of bound moisture in minced meat, was determined by pressing 0.3 g of the sample placed on an ashless filter between glass plates with 1 kg weight for 10 minutes. After this, the contour of the spot is outlined around the compressed sample; the contour of the wet spot appears on its own when the filter paper dries in air. It has been experimentally found that 1 cm^2 of wet spot area of an ashless filter corresponds to 8.4 mg of absorbed water. The mass fraction of bound moisture is determined by the formula:

$$WBC_w = (M - 8.4S) \times 100/m_0, \quad (2)$$

where M is the weight of moisture in the minced meat by weight, mg;
S is the area of the wet spot, mm;
8.4 is coefficient to transform wet spot area of an ashless filter to mg of absorbed water;
m_0 is weight of minced meat, mg.

Emulsifying ability (EA, %), of the obtained minced meat was determined using centrifugation of a homogenized sample with water and vegetable oil (Bozko et al., 2021). The results were calculated using the following formula:

$$EA = (V_1/V) x100, \quad (3)$$

where V_1 is the volume of emulsified oil, ml; V is the total sample volume, ml.

Thermographic analysis was conducted utilizing a Q-1000 derivatograph in an air environment within the temperature range of 15 to 800 ºC, with a heating rate of 10 ºC/min.

Statistical analysis

Statistical analysis of the experiment results was carried out using Statistica 6.0, Microsoft Office Excel 2007 and Mathcad. Data were expressed as mean ± standard deviation to define three measurements.

Results and discussion

It is known that the moisture content in meat can reach up to 75%, depending on the type of raw material, and processing can cause its transition from a bound state to a free state, but directly affect the quality of the resulting product (Aboagye et al., 2020). The production of semi-finished products includes the process of freezing, which, if not carried out correctly, destroys the structure of meat tissues (Dang et al., 2021). Such changes cause a deterioration in moisture binding, which in turn worsens functional and technological indicators. Meanwhile, the use of herbal additives in the recipe and the method of their hydration can significantly affect the functional and technological parameters and reduce the impact of changes caused by technological processing.

The moisture content was determined before freezing and after defrosting, and the study was conducted both for minced fillings and dough separately and for the whole dumpling. The results of the moisture content tests are shown in Table 3, 4 and 5.

Table 3

Moisture content of dumpling fillings

Samples	Moisture content,%		Moisture loss, %
	Before freezing	After defrosting	
Control 1	67.4±2.2	62.5±1.5	4.9
Control 2	65.2±1.4	63.8±2.0	1.4
Anolyte			
Sample 1	75.4±1.6	74.8±1.4	0.6
Sample 2	72.5±2.0	71.6±1.1	0.9
Sample 3	73.4±1.6	72.0±1.8	1.4
Sample 4	74.6±2.6	73.6±1.1	1.0
Catholite			
Sample 5	71.0±1.1	69.5±1.5	1.5
Sample 6	74.9±2.1	74.2±1.6	0.7
Sample 7	74.1±1.2	73.2±1.1	0.9
Sample 8	83.5±2.3	82.4±1.9	1.1

All samples have the moisture content above 60%, which is a sufficient value for this type of product. The samples with corn starch, activated water and hemp protein had increased moisture by 3.6–8.0% and with helm seed flour by 8.6 – 18.3 % compared to the control samples. Among the samples with hemp protein, sample 1 having content of hemp protein 14%, corn starch, 6%, and using anolyte for hydration showed the highest values of moisture content 75.4±1.6%; among the samples with hemp flour, sample 8 with hemp flour, 5%, corn starch, 15% and using catholite for hydration, had the highest moisture content 83.5±2.3%.

After defrosting, all samples showed decrease of moisture content and this moisture loss was smaller in experimental samples added with corn starch than in control samples without it. The meat mixture added with plant material and activated water demonstrated lower moisture loss, and sample 1 with a higher content of protein and anolyte showed a lowest moisture loss, 0.6%, while between the samples added with hemp flour, sample 4 with a higher content of starch had the lowest moisture reduction. The application of catholyte in similar formulations showed the opposite effect: in combination with hemp seed protein, the sample with a higher content of starch demonstrated more significant loss, and in combination with hemp seed flour, the sample with a higher content of flour.

In the production of the dough, drinking water or activated water was used for the corresponded dough formulations. The resulting dough was applied as a shell for the minced meat sample where hydration was carried out with the same type of water. Change in moisture content in dumpling dough shell was also examined, and the results are shown in Table 4.

Table 4

Moisture content of dumpling dough

Samples	Moisture content,%		Increase of moisture, %
	Before freezing	After defrosting	
Dough using drinking water	36.4±1.3	46.5±1.6	10.1
Dough using anolyte	36.6±2.2	42.7±1.3	6.1
Dough using catholite	35.6±1.2	39.2±1.6	3.6

Initial moisture content of all the dumpling dough was at the same level of 35.6–36.6%. However, after dough defrosting, there was a redistribution of water led an increase in its content in the dough. The largest increase of moisture content by 10.1% was in the control with drinking water. Increase of moisture content after defrosting in dough prepared with catholite was 3.6 and 6.2% in the dough made with anolyte.

The average meaning of moisture content, namely in minced meat in the dough, allows to assess the changes that occur in the product during the freezing process in general. The results are shown in Table 5.

Table 5

Moisture content of dumplings

Samples	Moisture content,%		Moisture loss, %
	Before freezing	After defrosting	
Control 1	56.0±1.4	53.1±1.6	2.9
Control 2	53.6±1.6	52.5±1.2	1.1
Anolyte			
Sample 1	59.9±1.1	58.0±1.4	1.9
Sample 2	58.1±1.5	57.5±1.8	0.6
Sample 3	58.6±1.4	57.2±1.6	1.4
Sample 4	53.4±1.5	52.6±1.2	0.8
Catholyte			
Sample 5	56.8±1.3	54.4±1.3	2.4
Sample 6	55.2±1.6	53.8±1.5	1.4
Sample 7	54.7±1.6	52.3±1.3	2.4
Sample 8	62.3±1.7	60.9±1.5	1.4

A higher moisture content was observed in experimental samples of dumplings in comparison with control. The highest value of moisture content was found in sample 8 with hemp seed flour and catholite used for hydration. After defrosting, all samples with a higher content of corn starch (2, 4, 6, 8) showed less moisture loss. It was confirmed for dumpling fillings, as well as for dumplings. These results could be explained by the fact that starch has a gelation capacity of 12%, which allows to form a stable matrix with water (Tafadzwa et al., 2021).

The state of moisture in the experimental samples can be assessed by determining the moisture-binding capacity of dumpling fillings (Figure 2).

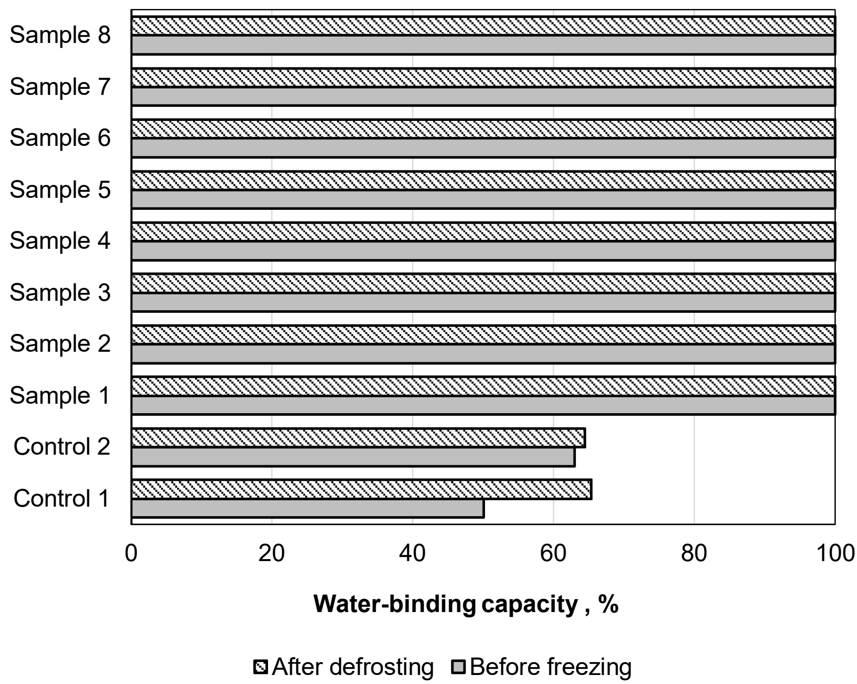

Figure 2. Water-binding capacity of dumpling fillings, %

Water-binding capacity (WBC_w) of the control increased significantly after thawing compared to the values before freezing. However, the values of the WBC_w for the dumpling fillings with corn starch and activated water remained unchanged after thermal exposure. It is correspond to the results of the study (Sá Júnior et al., 2021) showed that that the addition of 2% corn starch can increase the moisture binding in the meat product.

The water activity index (a_w) shows the amount of moisture available for microbial growth and indicates the stability of the sensory properties of meat products. It is know that at value of water activity below 0.85 the growth of bacteria is impossible. Proliferation of bacteria, yeasts, and mold could be observed at a water activity more than 0.95, meanwhile a_w of fresh meat is found to be around 0.99. The lowering water activity is preferable for extension of shelf life and prevention microbial spoilage of the product (Barcenilla et al., 2022). The water activity was measured in the dumpling samples after defrosting (Table 6).

The dumplings prepared with addition of hemp seed flour or hemp protein had water activity values, a_w, in the range from 0.955 to 0.971. Dumplings containing hemp protein (1, 2, 3, and 4) and corn starch had lower a_w values compared to control 1. On the contrary, dumplings with hemp flour (5. 6, 7, and 8) and corn starch had higher a_w values than the control 2. In all samples, regardless of the type of water used to hydrate the components, a decrease in water activity was found with an increase in corn starch content by 0.003–0.009 a_w, which shows the feasibility of introducing starch into the recipe for frozen meat products. Meanwhile, comparison of the samples with activated water, showed that lower a_w values were observed in the fillings prepared with anolyte.

Table 6

Water activity values in defrosted dumplings

Samples	Water activity, a_w of defrosted dumplings
Control 1	0.967±0.003
Control 2	0.955±0.002
Anolyte	
Sample 1	0.960±0.003
Sample 2	0.957±0.003
Sample 3	0.965±0.003
Sample 4	0.959±0.002
Catholyte	
Sample 5	0.966±0.001
Sample 6	0.961±0.003
Sample 7	0.971±0.003
Sample 8	0.962±0.001

The development of product formulations with electrochemically activated water with an acidic or alkaline pH inevitably changes this value in the product. Determination of the pH values was carried out in the dumpling filling before freezing and after defrosting (Table 7).

Table 7

pH of the dumpling filling

Samples	pH		Increase of pH
	Before freezing	After defrosting	
Control 1	6.40±0.02	6.40±0.02	0.05
Control 2	5.95±0.05	6.30±0.03	0.05
Anolyte			
Sample 1	5.83±0.03	6.22±0.03	0.39
Sample 2	5.88±0.03	5.98±0.03	0.10
Sample 3	5.86±0.02	5.94±0.03	0.08
Sample 4	5.85±0.04	6.20±0.04	0.35
Catholyte			
Sample 5	5.98±0.01	6.45±0.04	0.47
Sample 6	5.70±0.03	5.85±0.04	0.15
Sample 7	6.00±0.02	6.37±0.02	0.37
Sample 8	6.34±0.04	6.43±0.03	0.10

It was found that all dumpling fillings had initial pH in the range from 5.70 to 6.45. After defrosting, the values in the dumpling fillings did not increase significantly, except for control 1, where the pH did not change. The use of anolyte and catholyte in the formulations did not significantly affect the studied parameters. The difference in the pH values was only 0.15–0.49, and this change was most pronounced for the fillings with hemp seed flour.

The effect of application of activated water on pH of the dumpling dough shell is presented in Table 8.

Table 8

pH of the dumpling dough shell

Samples	pH		Increase of pH
	Before freezing	After defrosting	
Dough using drinking water	6.12±0.03	6.19±0.03	0.07
Dough using anolyte	5.86±0.03	6.51±0.04	0.65
Dough using catholite	6.26±0.02	6.31±0.04	0.05

The initial pH of the dough did not differ significantly, but slightly decreased after defrosting. In the dough prepared using anolyte, the largest increase in pH value by 0.65 units was observed. The difference in the pH value in minced meat fillings and dough shells is explained by the fact that the pH value of anolyte and catholyte is acidic and alkaline (Liu et al., 2021). Meanwhile, the use of starches in the filling does not have a significant impact on the pH value and its changes during freezing (Coria-Hernández et al., 2022; Eshag Osman et al., 2021).

The ability of minced meat to form emulsions in the protein-water-fat system allows to determine the functional and technological properties of minced meat. The stability and quality of minced meat system can be assessed by determining the emulsifying ability (Table 9).

Table 9

Emulsifying ability of dumpling fillings after defrosting

Samples	Emulsifying ability,%
Control 1	46.8±1.6
Control 2	45.5±1.3
Anolyte	
Sample 1	49.6±1.2
Sample 2	39.2±1.8
Sample 3	51.4±1.6
Sample 4	51.4±1.6
Catholyte	
Sample 5	43.3±1.7
Sample 6	44.5±1.1
Sample 7	45.9±1.9
Sample 8	43.8±1.3

Dumpling fillings had emulsifying capacity values in range from 39.2 to 51.4%. The fillings prepared using anolyte and hemp seed flour (samples 3 and 4) demonstrated the highest emulsifying abilities 51.4%. Filling 3 had the highest amount of hemp seed flour and lowest amount of corn starch, while filling 4 had the lowest amount of hemp seed flour and highest amount of corn starch. This is consistent with the experimental data of other scientists, who showed that vegetable proteins (Zhang et al., 2023) and starch (Gençcelep et al., 2017) can be used as stabilizers for meat emulsions.

Thermographic analysis was carried out on dumplings fillings with electrochemically activated water and different contents of hemp products and corn starch. For the study, the formulations 2, 4, 6, 8 were chosen. All these fillings contain 15 % of corn starch and 5% of hemp protein (samples 2 and 6) or hemp seed flour (samples 4 and 8). Anolyte was used for samples 2 and 4, while catholite was used for samples 6 and 8. The curves obtained for samples 2 and 6, which differed only by activated water taken for hydration are shown in Figure 3.

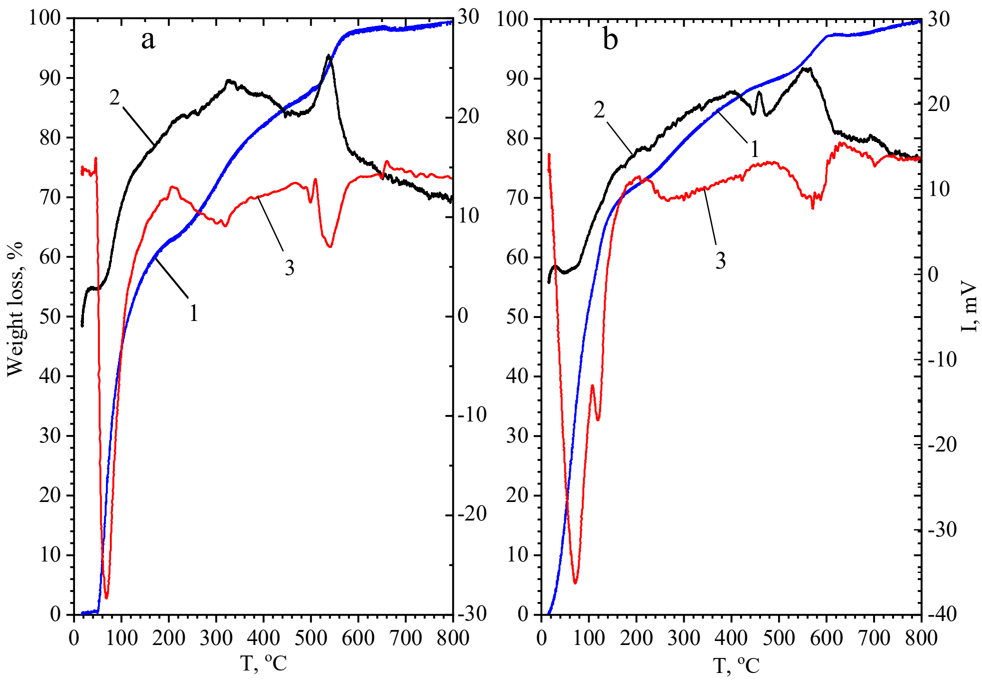

Figure 3 - Derivatization of dumpling filling using hemp protein, 5%, corn starch, 15%, and anolyte (a, sample 2) and catholyte (b, sample 6)

1, TG, thermogravimetry; 2, DTA, differential thermal analysis; 3, DTG, derivative thermogravimetry

In samples of the same recipe, but differing in water used for hydration of dry components, the maximum rate of mass loss in the samples is within close limits - 73 - 79 ° C. At the same time, the change in mass loss (TG curves) shows that for the sample using catholyte (Fig. 2b) the process losses begin at lower temperatures.

Analyzing the DTG curves for two samples 2 and 6, it can be noted that the maximum moisture loss at ~65 °C (accompanied by an endothermic effect on the DTA curve) is present for both samples, however, for sample 6 there is also an additional maximum at ~110 °C, which indicates better retention moisture sample treated with catholyte.

Similarly, the samples show some differences in the DTG curves in the temperature range of 200 – 400 °C, which illustrates the range of complete destruction (partial combustion, since an exothermic effect is observed on the DTA curve) of the protein: for sample 2, maximum weight loss appears at ~320 °C, whereas for sample 6 the maximum weight loss in this temperature range is ~260 °C.

The maxima on the DTG curve in the region of 500–600 °C (accompanied by an intense exothermic peak on the DTA curve) characterize the almost complete combustion of the organic component, and the profile of the corresponding maxima for samples 2 and 6 is slightly different. Finally, the highest temperature low-intensity maximum at ~650°C can be attributed to the complete burnout of residual coke or thermal decomposition of inorganic compounds.

It should also be noted that the TG curves for the studied samples show significant differences. In particular, the share of mass loss due to moisture removal (up to ~ 180 °C) for sample 2 (with anolyte) is about 60%, while for sample 6 (with catholyte) it is about 72%, which indicates a significantly higher moisture capacity of the latter.

Results of thermographic analysis of dumpling fillings with hemp seed flour are shown in Figure 4.

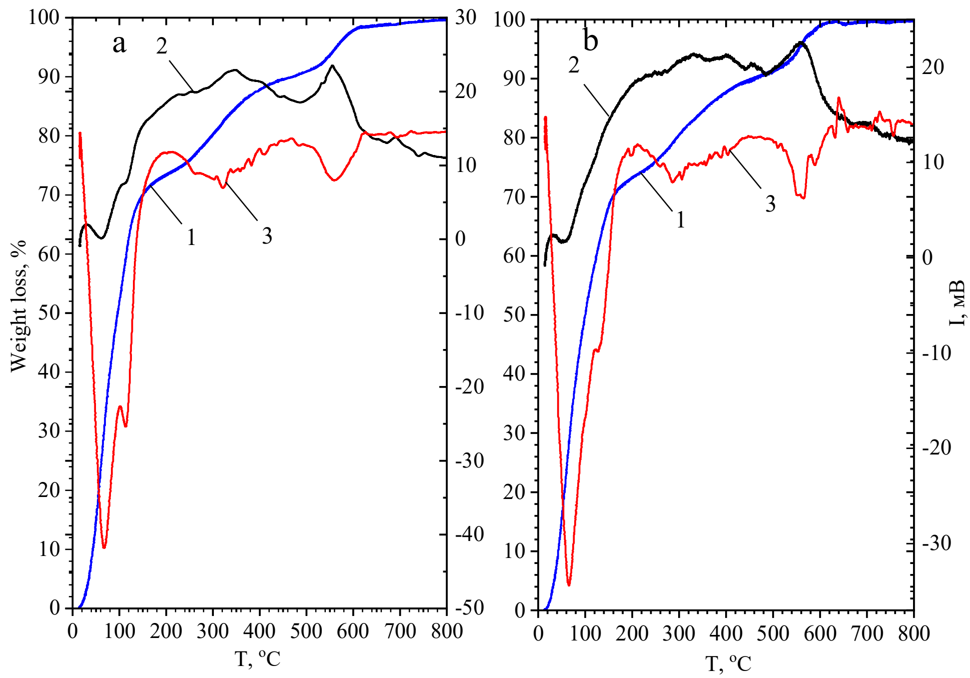

Figure 4 - Derivatization of dumpling filling using hemp seed flour, 5%, corn starch, 15%, and anolyte (a, sample 4) and catholyte (b, sample 8)

1, TG, thermogravimetry; 2, DTA, differential thermal analysis; 3, DTG, derivative thermogravimetry

Dumpling fillings with hemp seed flour show more similar curves of mass change during the heating process, but the process of these changes begins at a lower exposure temperature. The maximum rates of the mass loss in the samples range from 65 to 69°C. The changes in mass loss along the TG curve for both samples are quite similar.

The change in the mass loss rate during temperature exposure in the samples using hemp seed flour and anolyte shows three clear maxima, while the sample using catholyte has three clear maxima and one weakly visible one. For the sample with anolyte, the maxima were at temperatures of: 65°C, 120°C, 320°C, and 560°C, and for the catholyte at temperatures 60°C, 130°C, 280°C, and 560°C. This indicates that despite the fact that the process does not proceed the same when heating samples with different electrochemically activated water, the temperature of the final decomposition of proteins for the samples is within the same range.

The change in the DTA curve is similar for both samples and has one asymmetric endothermic maximum of water removal at ~ 65 °C and two heating exothermic maxima (decomposition of proteins and their complete combustion) at 340 ºC and 560 ºC for anolyte and catholyte.

The data obtained prove that the changes under the influence of heat occurring in the structure of minced meat systems depends on the raw material properties as well as on the characteristics of the water used.

Changes in the pH of the medium have a more pronounced effect on the experimental samples using hemp protein, where the sample with catholyte had a higher final conversion temperature. Whereas, when using hemp seed flour, both samples had similar characteristics and temperatures at which the conversion occurred.

Conclusions

1. The addition of corn starch in fillings of frozen semi-finished products helps to increase the moisture content and its binding. However, in case of incorporation of hemp protein, higher moisture binding was found for dumpling fillings with anolyte, but in case of addition of hemp seed flour, catholyte was more effective in increasing the moisture-binding abilities of the fillings. This is maybe due to different content of protein in hemp processing products.
2. Dumpling fillings with higher amounts of help processing products hydrated with anolyte had the highest emulsifying ability.
3. The use of an anolyte or catholyte had no significant effect on the pH of dumplings. However, the lower Aw values were observed in the dumplings prepared with anolyte that ensured their highest microbiological stability.
4. The results of thermographic analysis show that the use of catholyte in the dumpling fillings makes it possible to obtain the higher thermostability of minced meat.
5. Further studies will be aimed at determining the stability of the nutritional and biological value of the developed semi-finished products with a shell of dough during long-term storage.

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