Original scientific paper
UDC 637.5.03
664.9

NEW METHOD OF EMULSIFIED MEAT FOODSTUFFS MANUFACTURING

Andrey Bratsikhin[1*], Aleksey Borisenko[1]

[1]Institute of Building, Transport and Engineering, North-Caucasus Federal University, Kulakova avenue 2, 355029 Stavropol, Russia

[*]e-mail: aab.science@gmail.com

Abstract

The water-in-oil emulsions are widely used in the technology of emulsified meat products. Using the protein and fat emulsions in the technology of emulsified meat products gives the possibility to involve beef fat, connective tissue, pork skin, that are not suitable for this purpose in the native form.

The pH level and redox of activated liquids were determined by potentiometric measurement. The sensory methodology was used for the evaluation of the organoleptic characteristics of the meat products (appearance, odour, flavour, texture). Catolyte (CW) had produced by PEM-3 module, the value of catolyte pH is 10.45 - 11.2, Redox = (-300 ÷ -350) mV. The cavitation disintegration (CD) was carried out by ultrasonic treatment in homogenizer «Hielscher Ultrasound Technology UP».

Emulsions based on activated liquids obtained by cavitational disintegration, has high emulsifying capacity (up to 233 grams of fat per 1 g of protein). In that case sufficiently stable emulsions with a high fat phase (up to 60 - 70%) can be used. The best results for the preparation of high-quality emulsions obtained for CW + CD water and the production of the emulsion by cavitational disintegration. All sausage mincemeat which was produced with activated liquids had better properties than the control sample prepared using water. The optimal ratio of total moisture content (TW%) and water holding capacity (WHC%) was observed for the samples, which were produced with just using of catholyte and CD - catholyte. It was established that concentration of salt in the samples used the cavitation disintegration in their production higher up to 5.7 – 6.3% than in control.

The replacement of 15% raw meat by activated water hydrated protein "Kat-Gel 95" was recommended. The emulsions prepared by cavitation disintegrator more stable compared to a traditional method on homogenizer. Using of activated liquids instead of water allows excluding the water-holding chemical additives, improving the technological characteristics and producing the healthy meat products with high consumer properties.

***Key words**: Cavitational disintegration, Food emulsion, Meat foodstuffs, Stability, Emulsifying ability.*

1. Introduction

Water-in-oil emulsions are widely used in the technology of emulsified meat products manufacturing like boiled and grilled sausages, ham, chopped sausages. The emulsions can also be used in technology of combined meat products that include bacon, lumped meat, offal-content meat products, etc. Using the protein and fat emulsions in the technology of emulsified meat products make possible to involve beef fat, connective tissue, and pork skin that are not suitable for meat products in the native form. The optimal structural and mechanical properties of meat foodstuffs and reducing the losses of fat and water during heat treatment of them are obtained by adding the emulsions in meat foodstuffs formulation. The yield of sausages and frankfurters that are made with emulsions increases by 4 - 7%. Finely cut meat, water and fat are the main ingredients of emulsified meat products, and water and fat are dispersed to colloid system, and fat is trapped in space frame that is created by protein (meat protein or protein additives) with water (Zharinov [1], Chichko [2]).

Emulsion stability is one of the most importance qualities of emulsions and number of main factors influenced emulsion stability are (Tippetts and Martini [3], and Sathivel *et al*. [4]):

- type, formulation and functional properties of ingredients;
- quantity of salt-soluble proteins and their role in emulsifying process;

- the ratio of fat or oil and protein to water in emulsion;
- the order of ingredients addition in homogenizer, and time and temperature of dispersing process;
- the method is used for emulsion preparation.

A lot of different devices are used for emulsion preparation that implements various methods of forming of the stable emulsions (Figure 1). Recently, hydro-mechanical type of disintegrators is widely used in foodstuffs production (piston, centrifugal and slotted). The main disadvantage of such devices is in the cost of energy per unit of production. Hydrodynamic and impulse devices have a sufficiently high degree of dispersion (0.5 - 2.5 microns) but they do not force the cavitation effect that needs to effective dispersion of fat in emulsions (Shestakov [1]). As an alternative the acoustic cavitation devices are used for preparation of a high quality emulsions (Volokhova and Shestakov [6], Shestakov [7]).

Plant and animal proteins are commonly used as an emulsifier in many meat products due to their high nutrition value, low cost, functional properties that are similar to muscle proteins, and possibility to develop and stabilize quality of foodstuffs during their storage and transporting. Isolated soybean proteins and their concentrate are widely used in combined meat foodstuffs manufacturing. Zharinov [1] has reported that soybean proteins have a high water-holding and emulsifying capacity, and have a positive influence on muscle proteins hydration. The soybean protein concentrate is successfully used for recombined emulsions preparing at 20, 30 and 40% oil content (Borisova *et al*. [8]).

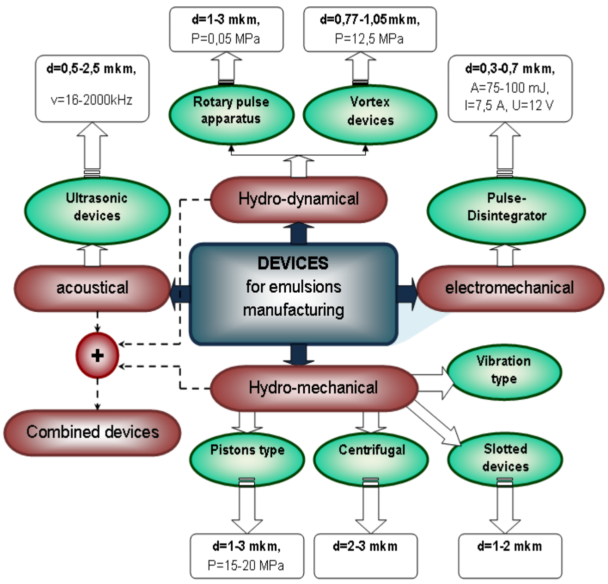

Figure 1. Scheme of classification of the devices used for emulsion preparation:
P - pressure of treatment, Pa; d - diameter of particles, mkm; A - work done by the device, mJ; I - amperage, A; U - voltage, V; v - audible frequency of ultrasound treatment, kHz; τ - duration of treatment, s

The main factor that limits the plant proteins using in meat technology is decreasing biological food value due to trypsin inhibitors and hemagglutinin proteins present, and organoleptical properties deteriorating. In that situation, the different animal proteins as the secondary resources of dairy and meat production are involved in modern meat foodstuffs formulation. Animal protein ingredients produced from hydrolyzed collagen are widely used for emulsified meat foodstuffs manufacturing.

The system's pH-level is one of the important factors influenced on the emulsion stability due to difficulties in providing desirable emulsifying properties at the isoelectric point of proteins (Baribina [9]). Chichko [2] have reported that quality, and microbiological and biological safety properties of emulsified meat products can be developed using catholyte of electrochemical activated water instead of water. The newest method of activated liquids production is cavitational disintegration that was studied in detail by Shestakov [10]. Morgunova *et al*. [11] have reported that cavitational activated liquids can be used for proteins functional properties regulation.

However, there is limited information available for preparing emulsion in meat foodstuffs production using cavitational activated water as a regulator of functional properties of the animal proteins. It may be possible to use cavitational activated water in emulsified meat foodstuffs production and to exclude phosphates as pH regulators from food formulation.

The first objective of this research was to study functional properties of collagen proteins with cavitational activated water and to develop emulsion using cavitational disintegration as a method of emulsion preparation. The second objective was to develop formulation and technology of sausage using developed emulsion.

2. Materials and Methods

2.1 Materials

The oil phase used for the formulation of emulsions was sunflower oil (Russian state standard 52465-2005, Aston Company, Rostov-on-Don, Russia). Collagen protein concentrate (CPC) "Kat Gel-95" (73.5% of protein content, Ness company, Germany) was used as emulsifier. NaCl (Russian state standard 13830-97, produced by Crimean Soda Plant, The Ukraine) was also used.

Fresh post-rigor pork and beef (mixture of *M. biceps femoris*, *M. semimembranosus*, *M. gracilis* and *M. adductor*) were obtained from a local meat plant. The meat was ground in grinder (82 Classic, Dadaux & Co., France) through 82 mm diameter plate having 3 mm diameter openings.

2.2. Methods

2.2.1 Meat systems design and preparation

The meat systems were designed to obtain three level of meat content (reduced 95%, 90% and 85%). Grinded beef was used for preparation of meat batters. Meat reduction was obtained by replacing grinded beef with added 5, 10 and 15% collagen protein concentrate "Kat Gel-95" previously hydrated by using types of activated water in ratio 1 : 4 (one part of concentrate and 4 part of activated water). One control meat batter was prepared containing 100% meat content with traditional water using. The preparation procedure was as follows: grinded beef was homogenized in mini-cutter (R8, Robot Coupe, France) for 1 min. Then hydrated collagen protein concentrate was added, and system was mixed at a low rate of knifes for 1 min.

Sausage batter performed as described in Technological Regulation of sausage "Buterbroadnaya" (9213-037-00420989-05, Russia), with slight modifications. Frozen lean beef, beef and pork were thawed and ground through an 8 mm plate. The formulation was 40% lean beef, 20% beef, 20% pork, 2% dried milk powder, 3% starch, 15% hydrated CPC "Kat Gel-95", 2.2% sodium chloride (NaCl), 0.006% sodium nitrite, 0.1% sugar, 0.04% milled coriander, 0.08% milled nutmeg, and iced water. The salts (NaCl and sodium nitrite) and sugar were dissolved in half of water and added to the ground lean beef. The mixture was chopped in a mini-cutter (R8, Robot Coupe, France) at high speed for 60 s. Then, ground beef and pork were added and chopped at high speed for 60 s. Finally spices and the rest of water were added and whole sausage batter was continuously chopped at low speed for 90 s. The final sausage batter temperature was maintained below 12 ^{0}C.

2.2.2 Preparation of cavitational activated water

Activated water was used as an aqueous phase in emulsion and water absorption capacity evaluation of emulsifier.

Three types of activated water were used in this study. Electrochemical activated water was produced by FEM-3 module (IZUMRUD Co., Saint-Petersburg, Russia) during electrochemical treatment of water (water electrolysis). Catholyte (CT) was produced at the cathode of device. It has the value of pH 10.45 - 11.2 and redox (-300 ÷ -350) mV.

Cavitational activated water (CD) was prepared by cavitational disintegration of water that was carried out in homogenizer «Hielscher Ultrasound Technology UP» (Hielscher Ultrasonics GmbH, Teltow, Germany) according to modes recommended by Shestakov [10]. Glass measuring cylinder with 150 ml of water placed under sonotrode of homogenizer. The sonotrode (diameter was 22 mm) was dip into water till the reflecting disk was placed on the water surface. Water was ultrasonic treated at 22 kHz and set 100% capacity (400 W) for 1 min. Cavitational disintegrated catholyte (CDC) was prepared at the same sets of treatment of catholyte.

2.2.3 Functional properties of emulsions

The water and fat absorption capacity (WA and FA) of the collagen protein concentrate "Kat Gel-95" was determined according to Gurova [12] using the mesh stainless steel cylinder with next size: diameter - 35 mm, height - 80 mm, diameter of openings - 1.5 mm, amount of openings per 1 cm^2 - 20. Cylinder, that wall and bottom were covered by filter paper, was dipped into water or sunflower oil for 20 min, and then took out for draining. Cylinder was weighted and 3 g of CPC sample put into it, and dipped again into water or sunflower oil for 20 min. Then cylinder with sample was drained for 20 min and weighted. Water and fat absorption capacity was calculated as ratio of sample mass after dipping into water or sunflower oil to initial sample mass.

Emulsifying and emulsion stability (EFS and ES) were analyzed to the method of Inklaar and Fourtuin [13]. A 1 g of CPC sample was placed in a 250 mL beaker and adding 25 mL of water. The sample was thoroughly homogenized at 3000 rpm for 2 min. After complete dispersion, refined sunflower oil was added from a burette at a rate of 0.4 mL/s and homogenizing continued until phase separation obtained. EFC was expressed as ml of oil emulsified per gram of protein.

Emulsion stability (ES) was calculated after heating of the emulsion prepared at EFS evaluate. From the emulsion, three 15 mL aliquots were taken and transferred into three beakers. The samples were heated at 85 ^{0}C for 20 min, and cooled to the temperature 20 ^{0}C. Then the samples were centrifuged at 6000 rpm for 30 min. ES was recorded in terms of phase separation and expressed as a percentage of initial sample height in beaker. These parameters were determinate in triplicate.

2.2.4 Meat batters characterization

Emulsifying and emulsion stability of meat batters were evaluated according to the method of Antipova *et al.* [14]. A 7 g of meat batter was transferred into 250 mL glass cylinder and adding 100 mL of water, and then mixed by blender at 650 rpm for 1 min. Then 100 mL of refined sunflower oil was added and the mixture was homogenized at 15000 rpm for 5 min. From the emulsion four 20 mL aliquots were immediately taken and transferred into four 50 mL centrifuge tubes and then centrifuged at 5000 rpm for 10 min. Emulsifying stability of meat batter (%) was calculated as [(total volume of oil - volume of free oil)/ total volume of oil)] × 100.

Emulsion stability was determined after heating at 80 ^{0}C for 30 min. and cooling for 15 min. by water with temperature 12 ^{0}C. From the emulsion four 20 mL aliquots were transferred into four 50 mL centrifuge tubes and then centrifuged at 5000 rpm for 5 min. Emulsion stability of meat batter (%) was calculated as [(total volume of oil – volume of free oil)/ total volume of emulsion)] × 100.

The pH was determined five times using pH-150 (WTW pH/Cond 340i) and couple of electrodes - glass ESL-15-11 and silver-chlorine half-cell EVL-1M4 (Russian State Standard 26781-85) on homogenate of 10 g of sample in 100 mL distilled water.

Total water content (TW) was estimated in triplicate according to method described by Zhuravskaya *et al.* [15]. Portion of sausage batter (approximately 5 g) was dried in glass beaker at 105 ^{0}C for constant mass reaching. TW (%) is calculated as [(initial mass of beaker and batter portion - mass of beaker and batter portion after drying)/(initial mass of beaker and batter portion - mass of beaker)] × 100.

Water binding capacity of sausage batter was determined as described by Antipova *et al.* [14]. Three portions of sausage batter (approximately 0.3 g) were weighted and placed on three ashless paper filters. Each filter was transferred on the glass plate and covered the same glass plate. On the glass plate put the mass 1 kg and hold for 10 min. Water binding capacity was calculated as [(total water content - 8.4 × square of moisture spot on the filter)/total water content] × 100.

Critical shear stress (CSS) was analyzed according to Antipova *et al.* [14] on Hoppler consistometer. Sausage batter transferred into glass cylinder and placed under cone of consistometer, and recorded the distance of dipping cone into batter for 3 min. CSS (Pa) was calculated as [mass of cone and arm × cone coefficient/ (distance of cone dipping)2]. Determinations were carried out six times at room temperature.

2.2.5 Sausage characterization

Water losses were determinate as a percentage weight loss after cooking on a thermal camera KON-5.

Yield of sausage was estimated as a percentage ratio of cooked sausage weight to mass of meat in formulation.

Penetration level was determined according to Antipova *et al.* [14] on Hoppler consistometer as a distance of dipping needle into cooked sausage for 3 min. Determinations were carried out six times at room temperature.

The sensory methodology (Zhuravskaya *et al.* [15]) was used for the evaluation of the organoleptic characteristics of sausage (appearance, odour, colour, flavour, texture).

The NaCl content in cooked sausage was measured in aqueous extract according to Mohr method as described by Antipova *et al.* [14]. Method based on the Cl-ions precipitation by Ag-ions in neutral medium at the present of K_2CrO_4 as catalyzer.

2.2.6 Statistical analysis

Statistical analysis of the results was performed and presented with MS Excel (Microsoft) and Statistica 6.0 (StatSoft, Tulsa, USA) at 95% level of confidence.

3. Results and Discussion

3.1 Functional properties of CPC characterization

In this experiment the different types of water were used for water absorption capacity of CPC evaluating: drinking water (W) with pH 7.85, catholyte (pH 11), cavitational disintegrated (CD) water with pH 8.5, and cavitational disintegrated (CD) catholyte (CD-catholyte) with pH 11.2.

Water and fat absorption capacities are an important functional characteristic of ingredients used in the meat manufacturing. Figure 2 shows WA with different types of water. All activated water increased WA for CPC due to higher pH level of them. The highest water adsorption capacity was obtained using of CDC for CPC hydration (677.3%). It is necessary to note that cavitational disintegration was more important factor influenced on the WA than pH of water. It can be explain more reaction ability of cavitational disintegrated water due to dissociation of hygrogen bonds between water molecules in clusters, and rising unstructured phase in water. The similar influence CD-water on biopolymers was noted and explained by Shestakov [16]. Fat absorption capacity of the CPC was 191.1%.

Emulsifying stability of CPC was analyzed at the different types of water using for emulsion preparation. In this study the comparative evaluation of different ways of emulsion preparing was done: traditional method using the homogenizer (cutter) and cavitational disintegration on the disintegrator «Hielscher». The emulsifying and emulsion stability can be demonstrated in form of emulsion condition diagrams (Figure 3 and Figure 4). Phase's ratio of emulsions prepared using two methods of their preparation were shown in Figure 3. Emulsions prepared by cavitational disintegration showed well EFS till the oil concentration 60-70% in contrast the emulsion prepared by homogenizer where oil phase was separated at 10 - 15% oil concentration. Oil separation rapidly increased at the 50% oil concentration using traditional method. At the same oil concentration the emulsion prepared by cavitational disintegration had the highest EFS 100 g of oil/g of protein without oil separation. Higher EFS could be explaining the partial hydrolysis of oil triglycerides, and glycerole and free fatty acids formation due to cavitational disintegration (Volohova *et al.*, [6], Shestakov [10] and [7]). Glycerole and free fatty acids are the emulsifiers and promote the self-stabilization effect in emulsions.

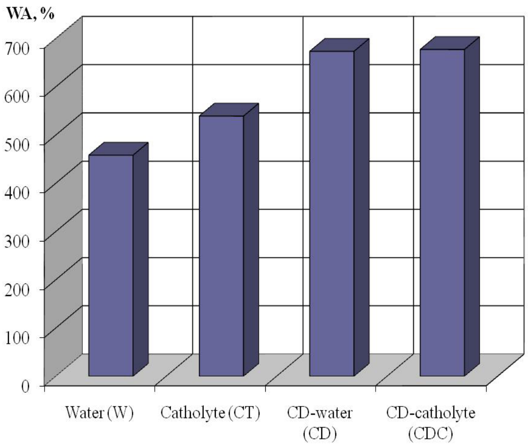

Figure 2. Water absorption capacity of collagen protein concentrate "Kat Gel-95" with different types of water using for hydration, P < 0.05

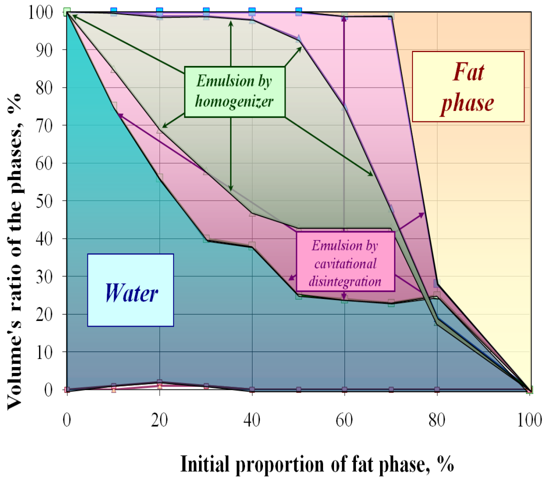

Figure 3. Phase's ratio of emulsions prepared using two methods of their preparation: homogenization and cavitational disintegration

Figure 4 show the phase's ratio of emulsions prepared using all types of activated water and control sample with traditional water. Every emulsion was prepared by cavitational disintegration. The EFS of emulsion prepared on the CDC water was 233 g of oil/g of protein, and the same property of emulsion prepared on CT was 150 g of oil/g of protein. In samples with using CDC and CT as compared with control sample the EFS was higher and oil separation was indicated at the 70 - 80% of oil. On the other hand, emulsion prepared on the CD-water had the similar EFS value to the control sample. There is no clear relationship between type of water and preparation method, but it may be related to the bonds breaking that have been formed at the hydration of CPC before treatment. Since these emulsions must be considered in the context of their practical use in emulsified meat products manufacturing, for these purpose they needed to be prepared on the CDC-water by cavitational disintegration.

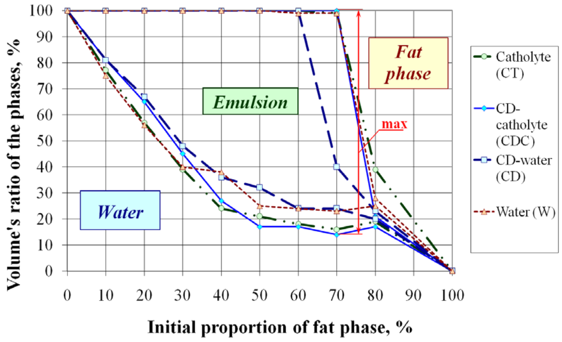

Figure 4. Phase's ratio of emulsions prepared using all types of activated water and control sample with traditional water

3.2 Meat systems characteristics

In this experiment meat batters with different levels of replacement of meat in sausage formulation by emulsion were produced for study the main characteristics of meat batter such as emulsifying and emulsion stability that had to be considered as the affect the quality of reformulated sausages. There were three levels of replacement of meat by emulsion - 5, 10 and 15%. Emulsions were prepared by cavitational disintegration of CPC and water in the ratio1:4 with using CT, CD, CDC and W respectively. Meat batters were obtained by cavitational disintegration.

Emulsifying stability of meat batters at the 5, 10 and 15% replacement levels are presenting in Figure 5. Samples were prepared with CT-water and CDC-water had higher EFS (118 and 118.2% respectively) compare to other batters. The similar character had the emulsion stability. Meat batters prepared with CT and CDC-water were more stable at the all levels of meat replacement. Compare to the control sample, batter made with CD-water had higher ES. Concluding, sample prepared with CDC-water and 15% level of meat replacement had higher functional properties and therefore was recommended to the next step of study.

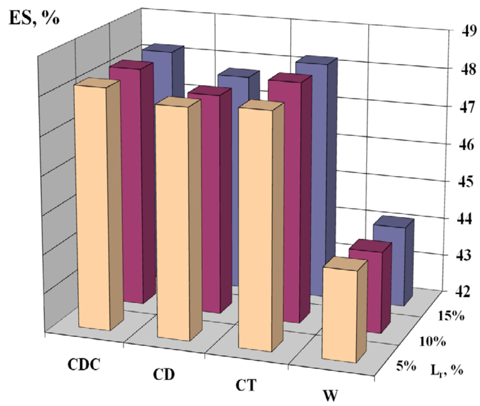

Figure 5. Emulsifying stability (ES,%, P < 0.05) of meat batters at the 5, 10 and 15% replacement levels (Lr, %) of meat by emulsions (hydrated CPC)

At this step the next main characteristics as pH, water binding capacity and critical shear stress were analyzed for sausage batter prepared according to formulation of sausage "Buterbroadnaya" with replacement of hydrated soybean concentrate by emulsion of CPC. There were four samples prepared. The difference in samples formulation was in the type of water used for emulsion preparation and adding to the batter as formulation's water.

In Figure 6 pH of the sausage batter samples prepared with different types of water is depicted. Sample's pH depended on the pH level of water used for their preparation. The result of using activated water with high pH was in displacement of batter's pH to the higher level from the isoelectric point of meat proteins. It was verified by the pH of the samples. The samples produced with CT and CDC had pH 5.53 and 5.61 respectively. Cavitational disintegration did not significant increase the pH of water therefore the influence CD on the batter's pH had not established. The pH level of batter prepared with CD was 5.40.

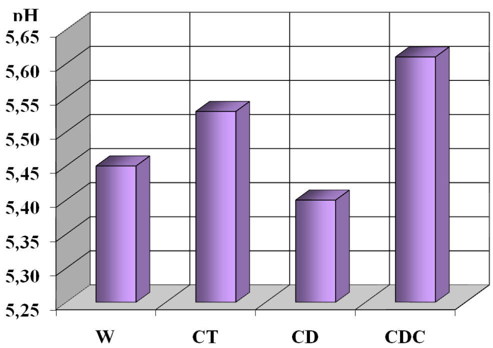

Figure 6. pH of the sausage batter samples prepared with different types of water (P < 0.05)

Water binding capacity had been calculated at the total water content of the samples was in correlation relationship with the batter's pH (Figure 7). Every batters prepared with activated water had WBC higher than in control sample (59.8%). The optimal relationship between total water content and WBC was indicated in batters prepared with CT (70.7% and 66.3%) and CDC (74.5% and 65.1%). The mechanism of water binding capacity is thought to be mainly due to high water absorption capacity of CPC and high pH of sausage batters.

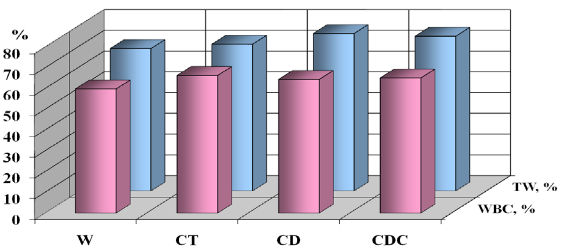

Figure 7. Water binding capacity (WBC, P < 0.05) and total water content (TW, P < 0.05) of the sausage batter samples prepared with different types of water

Critical shear stress was used to characterize textural properties of sausage batters. In the samples prepared with activated water as compared with control sample the activated water using produced harder (P < 0.05) meat structures. Sausage batter made with CT had lower critical shear stress (1943.9 Pa), formed homogeneous viscoplastic structure due to intensive extraction of the salt- and watersoluble proteins and their high hydration ability that was promoted by reaction properties of activated water. Same effect was noticed by Chichko [2], Borisenko *et al*. [17], Morgunova *et al*. [11].

The main characteristics of cooked sausages are listed in Table 1. Sample prepared with CDC using had a higher yield (137.6%) than other samples and, as compare with control sample, was increased by 8.6%. It is necessary to note that this rising of yield was provided by activated water using only without chemical regulators of pH. This sample had greater physical-chemical properties and organoleptic evaluation (4.7). It was indicated that sample prepared with CDC had higher level of total water content (70.76%) that was hold tightly in the cooked sausage (WBC was 62.4%). The same characteristics of sample prepared with CT slightly lower than in previously sample. The sample yield was 135.8%, TW and WBC were 68.67% and 61.3% respectively, and sensory estimated was 4.5. Additional treatment of catholyte by cavitational disintegration promote rising of sausage yield by 1.8%. Using CD-water for sausage manufacturing provided rising the sample yield by 5.4% as compare with the control sample. But the effect of two-stage activating by electrochemical treatment and cavitational disintegration had more significant influence on the quality properties of sausage.

Table 1. Main characteristics of cooked sausages

Properties	Control sample	Experimental samples with			Δ *
		CT	CD	CDC	
Total water content (TW. %)	64.20	68.67	64.81	70.67	0.27
Water binding capacity (WBC. %)	54.60	61.30	59.90	62.40	0.30
pH	6.17	6.19	6.21	6.22	0.02
Water losses. %	6.10	2.10	3.20	1.41	0.02
Yield related to raw meat (%)	129.00	135.80	134.40	137.60	0.32
Penetration level. mm	4.80	4.50	4.50	4.40	0.015
NaCl content. %	1.740	1.740	1.850	1.840	0.005

* Δ (Standard deviation).

Penetration level of sample prepared with CDC (4.4 mm) was lower than in other samples. It was noted that samples prepared with activated water had higher hardness and springiness due to lower level of unbound water. This effect was confirmed by value of water losses that was lower than in other samples, and high levels of total water content and WBC.

Concentration of NaCl in the samples prepared with CD and CDC-water was lower by 5.7 - 6.3% as compare with control sample. The same effect was reported by Shestakov [10] and correlated with our early research (Bratsikhin *et al*. [18]), and connected with intensive dissociation of NaCl during cavitational disintegration. These results show that technologically possible to reduce by 6% NaCl amount in formulation of sausages with using CDC-water for their manufacturing without undesirable influence on sensory characteristics. Such sausages may be recommended for people that have metabolism problems.

4. Conclusions

- Cavitational disintegration was recommended as a method of stable emulsions preparation. Activated water offer the opportunity for preparation of water-in-oil emulsions with higher functional properties that given the possibility of their using for emulsified meat products manufacturing.

- Emulsions prepared with sunflower oil (as a lipid phase), collagen protein concentrate "Kat Gel-95"as hydrophilic emulsifiers and cavitational disintegrated catholyte with pH 11.2 showed good stability with higher concentrate of fat phase (60 - 70%) without using of chemical stabilizers.

- Cavitational disintegrated catholyte was also recommended for hydration of added protein concentrate and preparation emulsions for sausage production. When emulsions used as meat replacers, they affected the physicochemical properties (water binding capacity, pH, texture) of emulsified meat systems.

- The study showed the possibility of 15% replacement of meat by hydrated CPC in sausage formulation. Reformulated sausage batter had good functional and physicochemical properties that promoted the manufacturing of sausage with higher sensory characteristics, reduced NaCl content and yield without phosphates using.

- This study confirms the feasibility of using activated water as a technological factor of functional properties regulation for the development of healthier meat products.

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