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Studying Chemical Composition and Yield Stress of Micronized Grinded Cattle Bone Paste.

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ABSTRACT

In this study the chemical composition and yield stress of meat bone paste is studied. The meat-bone paste is obtained after grinding on colloid and superfine colloid machines with final size of bone particles less or equal to 0.1 mm. According to the analysis, the protein content in meat-bone paste was 24.30%-24.72%, fat content is varied from 11.0% to 12.7%, moisture – 33.89%-34.47% and inorganic substances reached up to 30% from the total mass of the meat-bone paste. The yield stress of meat-bone paste after grinding on the colloid machine (MBP1) varies from 19231.04 Pa to 6934.56 Pa and from 18182.09 Pa to 5944.47 Pa in MBP2 (meat-bone paste after grinding on the superfine grinding machine) in the range of temperature from 10˚C to 30˚C.

Keywords: meat-bone paste, yield stress, temperature, composition, superfine

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INTRODUCTION

Today, there are a huge number of formulations and technology of functional, healthy and dietary foods. Fortification with essential and vital nutrients happens due to the addition of protein compounds, biologically active substances, plant origin materials and etc.

Due to the nature of composition and properties one of the less-used types of cattle by-products in the food industry is a bone [1]. The presence of high-digestibility proteins, fats, phosphorous and calcium salts, macro- and microelements, vitamins and amino-acids is the reason of using of bone into the formulation of various food products [2]. In traditional technology the cattle bone is used for production of bone fat, broth, feeding meal and also for extraction of protein and mineral components by the method of acid and alkaline treatment for further utilization in the food technology.

Rational utilization of cattle bone, implementation of wasteless and low-waste technology that eliminates, or at least minimizes losses and provides enhanced quality of food is played an important role during the meat processing in all stages of the production [3].

Carcass or part of carcass consists of muscle, fat, connective and bone tissues. Proportion of these tissues in the carcass, approximately: muscle tissue – 50÷70%, fatty tissue - 3 ÷ 20 %, connective tissue - 9 ÷14 %, bone tissue - 15 ÷ 22 %. During the boning it is difficult to completely separate muscle and connective tissue from the bone and thus the remaining tissues on the bone is on average 8.5 %.

Bone received after meat processing is characterized by high content of fat, protein and phosphorus-calcium salts. Chemical composition of bone is represented by: water – 13.8-44.4%, protein (collagen) – 32.0-32.8%, mineral elements – 28.0-53.0%, fat – 1.3-26.9% [4, 5].

Traditionally the meat and bone meal is used in the formulation of animal feed, glue and gelatin, in the production of dried pet foods, however in food industry the experts develop different protein additives and mineral supplements from meat-bone raw materials. [2, 6, 7].

The most characteristic components of bone are mineral elements, represented by calcium salts of carbonates and phosphoric acids. Around 99% of all calcium is concentrated in skeleton. The mineral content of bone tissue characterized by next oxides (%): CaO – 52; MgO – 1,2; P2O5 – 40,3; Na2O – 1,1, K2O – 0,2; Cl – 0,1; F – 0,1; CO2 – 5,0 [8, 9]. Thus, the bone of cattle is the supplier of large amount of calcium and phosphorous salts. According to Drake et al. [10] bone is a useful calcium source for nutrition because bone particles are easily soluble in gastric juice. The use of these mineral salts in the technology of meat foods enables enrichment the food with mineral supplements, particular with calcium, phosphorous, magnesium and other elements. It is known, that the content of calcium in beef varies between 9-14 mg/kg and during the consumption of meat products the human body absorbed insufficient amount of calcium. A calcium deficiency causes osteoporosis [11].

Particular emphasis should be placed to the superfine bone grinding process. Superfine grinding technology is produced superfine powder with good surface properties like dispersibility and solubility [12]. The superfine grinding technology of raw bone allows getting the product like paste, soft in texture and full digested in human body. This paste will be used in production of food supplements. Superfine grinded meat-bone paste will be used during the production of different type of meat products – sausage, pate, semi-finished meat products et.c. As the meat-bone is grinded without any thermal treatment it possess with valuable vitamins, protein and mineral substances [13].

For obtaining the fine graded meat-bone paste the meat bone is grinded mainly on power crushing machines, hammer crushers, milling grinders et. c. During the grinding process the bone is exposed to the external factors to change the intrinsic properties, including rheological properties. Rheological properties of foods mainly characterized by compression, shear and surface properties. Shear properties describe the deformation process of sample under the shear stress, which include yield stress, viscosity, relaxation phase [14, 15].

Yield stress is a material property which denotes the transition between pseudo-solid and pseudo-liquid behaviors – related to minimum shear stress at first evidence of flow – or transition from elastic to viscous deformation [16]. This is a non-Newtonian effect [17] and understanding of yield stress in foods is important for several practical applications – from process calculations to product development [18]. Product composition and processing conditions affect product texture [19, 20].

The method of determination of yield stress is penetration techniques. Penetrometers have been used widely for testing the rheological properties of materials of high consistency [21]. Penetrometry is universally available and allows quick and accurate measurement of consistency of raw material, semi-finished and ready products. Penetrometers can more fully characterize the structure and shear phenomena in minced meat and sausages. Comparing with plastic and effective viscosity, yield stress is more sensitive to changes in technological (moisture, fat content, pH) and mechanical (mincing, mixing) factors [22, 23].

The purpose of this study is to investigate the chemical composition of the meat-bone paste and the influence of temperature to the yield stress of meat-bone paste, obtained after mechanical processing on the grinding machines.

MATERIALS AND METHODS

Meat-bone paste processing technology

Rib bones of cattle were obtained after boning of carcasses at the sausage company in Semey city (Republic of Kazakhstan). Total weights of bones were 50 kg and transported to the lab and stored at the temperature of (-18) ^{0}C.

According to the processing scheme of meat-bone raw material, the rib bones were crushed until 50-70 mm of length. After that, these bones were frozen to (-18) ^{0}C – (-20) ^{0}C and loaded into the hopper off crushing machine with 8 mm diameter of meat grinder plate and grinded. Given grinded meat-bone was crushed one more time, but with the meat grinder plate of 5 mm. After crushing machine the meat-bone was frozen to (-18) ^{0}C – (-20) ^{0}C and grinded on a colloid mincing machine with the 0.6 mm diameter of bone particles outputs. For superfine grinding the meat-bone paste was grinded on a micromilling machine “Supermasscolloider MKZA-10-15” with the gap of 0.1 mm between the rotational knives.

Colloid grinding machine is a rotor grinder with the set of fixed and moveable knives. Grinding rate is depending on the gap between the knives and bone particle size after grinding is up to 0.5 mm. This machine consists of screw feeder, frame, housing, knife head, rotor and unloading passage.

Superfine grinding machine “Supermasscolloider MKZA 10-15” (Masuko Company, Japan) produces ultra-fine particles which look almost like paste. The Supermasscolloider ultra-fine grinders feature two ceramic nonporous grinders, which are adjustable at any clearance between the upper and lower grinder. Using ceramic grinders enables production of particles that are more round shape and smoother-with a more uniform grain size-than by other crushing methods [24].

Yield stress measurement

Yield stress is measured using cone penetrometer “Structurometer” (“Radius” Company, Russia). It is used for measuring the rheological parameters of food in various field of food industry.

Method of sample preparation and measurement as follows: the sample of forcemeat is filled into the container and slightly pressed leveling the surface of the sample. Then the container is placed to the air or water bath under the temperature of (10-30) ^{0}C for the sufficient time of heating the sample until (10-30±0,5) ^{0}C. After that, the measurement is performed in accordance with the operational instructions of the device “Structurometer”. The operation principle is based on penetration of stationary indentor to the sample, moved up by constant speed for determination of rheological properties of food materials [22].

Given the fact that “Structurometer” displays the value of loading instead of mass of cone with stock and penetration depth in mm, the yield stress is calculated by eq.1:

$$\sigma_0 = K \cdot \frac{P \cdot 9{,}81 \cdot 10^3}{h^2}, \text{ Pa} \quad (1)$$

Where
P – penetrating load g;
h – immersion depth of cone, mm.
Consequently, the constant of cone, as applied to the cone of the device:

$$K = \frac{\cos^2(\alpha/2)}{\pi \cdot tg(\alpha/2)}, \quad (2)$$

where, α – angle at the vertex of the cone (α=45° и α=60°).
Arithmetical mean of yield stress for each variant of sample:

$$\sigma_0 = \frac{\sum \sigma_i}{i}, \quad (3)$$

where, i – number of measurements.

The yield stress was measured on different temperatures between 10˚C to 30˚C. The temperature of meat-bone paste was controlled by the water bath for 15-20 min at the given temperature.

Determination of bone particle size

For determining the bone particle size we have observed the microstructure of bone particles on the scanning electron microscope SEM "JSM-6390LV" (JEOL Company, Japan). For preparing the meat-bone paste to scan, the sample was heated in a boiling water bath and treated with 2% NaOH for full decomposition of meat tissue. After heating the solution was passes through the filter. Remained bone particles were dried at 103-105 ˚C during 15 min in the drying oven. Then the dried bone particles were observed on the SEM.

Chemical composition of meat-bone paste

Determination of total chemical composition of meat-bone paste is based on the consistent determination of moisture, fat, ash and protein in one hinge-plate.

Determination of moisture content

The sample of meat-bone paste was weighted to 2-3 g, to the nearest 0,001 g, and placed into the metallic cup. Then it was dried at a temperature of 150^{0}C for 1 hour in the drying oven.

According to the standard GOST 9793-74 [25] and GOST R 51479-99 [26], the moisture content is calculated by equation 4:

$$x_1 = (m_1 - m_2) \cdot 100/(m_1 - m), \quad (4)$$

where x_1 – moisture content, %;
m_1 – weight of sample with cup before drying, g; m_2 – weight of sample with cup after drying, g;
m – weight of cup, g.

Determination of fat content

After determination of moisture, the dried sample was moved to the glass cup. Then 10-15 ml of ethylic ether was poured to the glass and periodically mixed during 3-4 min. While the extracting process the ethylic ether with the fat poured out and filled with new ethylic ether. After 4-5 replication, the residue of ethylic ether was evaporated at room temperature. The metallic cup with extracted fat sample was dried at the temperature of 105^{0}C during 10 min. According to the standard GOST 23042-86 [27] the fat content was calculated by equation 5:

$$x_2 = (m_1 - m_2) \cdot 100/m_o \quad (5)$$

where x_2 – fat content, %;

m_1 – weight of sample with cup after drying before extracting, g;
m_2 – weight of sample with cup after extracting, g;
m_0 – weight of cup, g.

Determination of ash content

The given sample after extraction was placed into the weighted and preheated crucible. Then 1 ml of magnesium acetate was added to the crucible and burned on the electric hot plate. After that it was placed into the muffle furnace for 30 min with the temperature of 500^{0}C – 600^{0}C. The magnesium acetate was

The ash content was calculated by equation 6:

$$x_3 = (m_1 - m_2)\cdot 100 / m_0, \qquad (6)$$

where x_3 – fat content, %
m_1 – weight of ash, g;
m_2 – weight of magnesium oxide, obtained after the mineralization of magnesium acetate, g;
m_0 – weight of sample, g.

Determination of protein content

According to the standard GOST 25011-81 [28] the protein content was calculated by equation 7:

$$x = 100 - (x_1 + x_2 + x_3), \qquad (7)$$

where x – protein content, %
x_1 - moisture content, %;
x_2 – fat content, %;
x_3 – ash content, %.

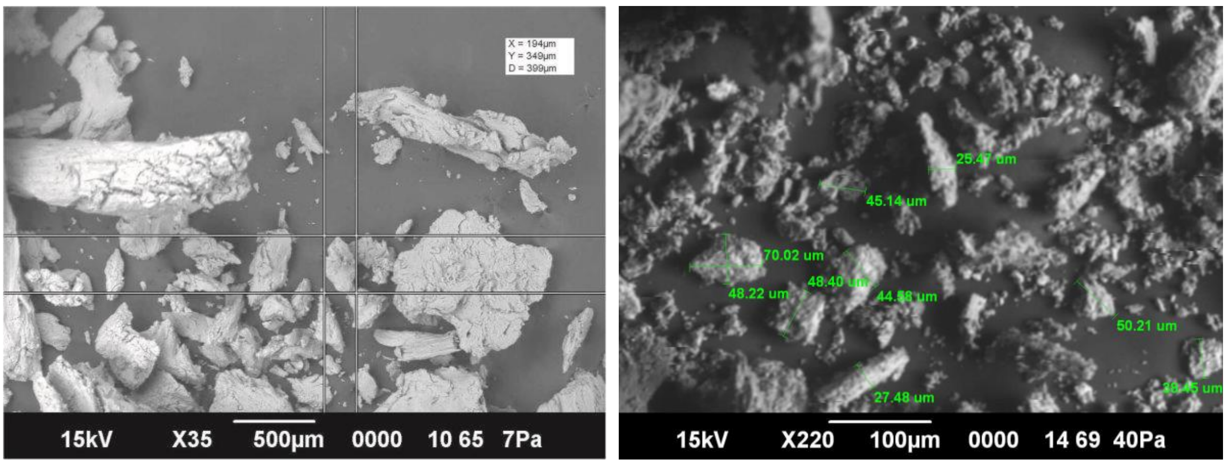
Statistical analysis

Statistical analysis was performed with Statistica 6.0 and Excel 2007.

RESULTS AND DISCUSSION

Size distribution of bone particles

Meat-bone particle size after grinding on the colloid mincing machine is varied from 0.2 to 1.5 mm. After grinding the meat-bone paste on the superfine grinding machine the particle size with more than 0.1 mm (100 micron) has not found (fig.1).



a) bone particle size after colloid grinding   b) bone particle size after superfine grinding

Fig: 1. Bone particle size of meat-bone paste after grinding

On the next stage of the study we determined the chemical composition of meat-bone paste after grinding on the colloid milling machine and ultra-fine friction grinder "Supermasscolloider" (table 1).

Table 1: Chemical composition of meat-bone paste and ground meat

Parameter, %	MBP-1	MBP-2	Ground meat
Moisture, %	34,47±0,64*	33,89±0,92	67,67±0,83
Fat, %	11,00±0,59	12,70±0,51	17,81±0,64
Ash, %	29,81±0,72	29,11±0,89	2,66±0,44
Protein, %	24,72±0,65	24,30±0,87	11,64±0,57
MBP1 – meat-bone paste after colloid milling machine MBP2 – meat-bone paste after ultra-fine friction grinder "Supermasscolloider"			

*Mean±SD – mean value ± standard deviation (p≤0.05) – statistically significant difference amongst the samples

Bone chemical composition varies with the breed and body condition and type of bone of the animal: with growing up the weight of the animal the content of fat and mineral elements is increasing but the water content is decreasing. In vertebra bones this phenomenon can be seen from the head to the back side of meat carcasses.

Bone protein mainly consists of collagen. By the investigation, the protein content in the meat-bone paste was 24.30-24.72%. The fat content varies from 11.0% in the meat-bone paste after grinding on the colloid machine and 12.7% in the meat-bone paste after grinding on the masscolloider.

It is commonly known, that the bone is a source of mineral elements, particular rich with the salts of calcium (to 85%), phosphorous, magnesium, sodium, potassium, iron and et.c. [4]. The total amount of inorganic substances in MBP-1 and MBP-2 is about 30% from the weight of meat-bone paste.

On next stage, the yield stress of meat-bone paste after grinding was determined. The results are shown in the table 2.

Table 2: Yield stress of meat-bone paste, Pa

Temperature, ˚C	Yield stress, Pa		
	MBP-1	MBP-2	Ground meat
10	19231,04±149,05	18182,09±161,73	5090,52±144,47
15	16375,59±155,31	12989,59±238,42	3516,27±90,40
20	11954,48±116,85	9048,34±98,06	2334,68±100,59
25	8727,58±160,85	7700,85±134,34	1603,77±95,00
30	6934,56±176,58	5944,47±122,46	1408,97±136,05

*Mean±SD – mean value ± standard deviation (p≤0.05) – statistically significant difference amongst the samples

The highest value of yield stress (19231.04 Pa) was observed in the MBP-1 whereas the yield stress of MBP-2 was 16043.02 Pa at temperature of 10 ˚C. The difference of yield stress of meat-bone pastes can be explained as a result of the sizes of bone particles. During the analyzing the particle size, the particles of MBP-1 were 0.3-0.6 mm and of MBP-2 were around 0.1 mm. Finer grinding of meat-bone paste leads to intensively chafing of the bone particles and tissues which encourages the transition of free water to the surface-bounded water and thus changing the yield stress.

With temperature increase to 30 ˚C the yield stress of meat-bone paste had decreased until 6368.47 Pa in MBP-1 and 3236.45 Pa in MBP-2.

In ground meat the yield stress is changed from 5090.52 Pa at 10˚C to 1408.97 Pa at 30˚C.

The highest drop of the yield stress (up to 72% from the initial value) was observed in the minced meat, and up to 67% the yield stress was decreased in the MBP-2 and until 64% in the MBP-1. The most dramatic change of the yield stress was occurred in the temperature range from 15˚C to 20 ˚C (from 21% to 23%) (fig.2). It is observed, that the yield stress changing less significantly with increasing the temperature of meat-bone paste.

The yield stress value of minced meat is 3 times lower than the yield stress of meat-bone paste. Minced meat has soft and fluid consistency because of higher moisture and low ash content.

Significant yield stress difference of meat-bone paste and minced meat depend not only the moisture and inorganic substances, but the protein. Bone protein mostly consists of collagen, its particles has elongated fiber shape which form strong intertwined fibers.

Similarly to our study, Ibragimov N.K. [29] studied the yield stress of chicken bone after grinding on the colloid machine. It is observed, that the yield stress and water holding capacity WHC are raised as the speed of knives is increased. The most high value of the yield stress (943.29 Pa) and WHC (66.98%) is observed with the speed of knives of 4000 rpm and gap between knives of 0.16 mm, while the most low value of the yield stress (635.87 Pa) and WHC (63.38%) is detected with the speed of knives of 1000 rpm and gap between knives of 0.38 mm. It was found out that while increasing the rotational speed of knives and decreasing the gap between the knives, the power consumption of electric motor is increased. Abdilmanov investigated the impact of grinding process to the yield stress and water holding capacity of chicken meat-bone paste. Water holding capacity of chicken meat-bone paste reached to 67-69% and the yield stress varied between 648.41 Pa to 712.65 Pa [30].

CONCLUSION

Chemical composition of meat-bone paste mainly consists of inorganic chemicals – mineral salts of calcium, phosphorous, and collagen. Yield stress measurement is the main rheological parameter to mind during the formulation of meat products. Higher values of yield stress of meat-bone paste demonstrated the dense consistency because of insufficient content of moisture in it. Further studies on physical and chemical and rheology properties of meat-bone paste and the ways of rational utilization as functional ingredient in production of foods are clearly needed.

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