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The Optimization Additive's Mixing Processes in Based on Their Thermodynamic Characteristics During the Production Food Products with Long Shelf Life

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Abstract: The mixing order of components during the production of multi-component food product plays key role in formation of its organoleptic properties and stability. It depends on the interaction of systems like "oil-water", "water-protein", "carbohydrate-water" and "water-gas". The during the research was proposed the technology of boiled-smoked meat-vegetable products made from sub-products and vegetable raw materials with the use of regression-hydration technology. Many formulations were tested and were screened in order to obtain the best result. Also, thermodynamical properties, chemical and nutritional content of these products were examined. It was concluded that using of regression-hydration technology allows saving its quality and ensuring the specified shelf life.

Key words: Regression-hydration process, multi-component food products, sub-products, mixing order, formulations

INTRODUCTION

During the production of food products step of the mixing plays key role because it affects organoleptic properties and the stability of the final product. Now a days, the theory of the food structure's stability has a number of problems because there is a lack of clear understanding of the mechanism of structure formation of food. First of all, it is due to there is no clear understanding of the nature of the interaction "oil-moisture", "moisture-protein", "carbohydrate moisture" and "moisture-gas systems". Hydration of food components determines its rheological and other physico-chemical properties and therefore, the study of the behavior of moisture in biological systems is still an actual problem. Considering food as a complex moisture-polymer system where the predominant component is moisture that in the continuous phase, to describe its state the laws of thermodynamics are convenient.

Based on the fundamental studies of Polanyi and Rebinder that offer as an only correct parameter of relation of moisture and product components by evaluation its energy, we look at its main conditions. Considering the fact that the energy of the moisture is a specific value then for the real system of its total binding energy or enthalpy of the moisture connection will depend on the mass of moisture contained in the system and describes the relationship (Kamerbaev, 2001). If we assume that hydration levels of the components of this product affect the stability of food structures, obviously, it is necessary to study the structure formation functions responses from the various physico-chemical and technological factors. As its well known that food product is a complex biotechnological system which contain proteins, fats and carbohydrates and their hydration properties are individual and unpredictable.

Due to these features and to understand whole hydration mechanism of food product we are decided to research which can explain how these components and their mixing order affect technology of food systems production. In the studies carried by Kamerbayev A. technologies of sausage products with use of regression-hydration technology were developed. Studies were focused on to determine the physico-chemical and technological factors affecting the stability and sustainability of structures (Kamerbaev, 2001).

The researchers concluded that to achieve the best picture of drawing up a multi-component system (emulsion) on the basic physical, chemical and technological parameters can be based on the knowledge of the value of the enthalpy of moisture binding which in this scheme of mixing has decreasing (regression) order that procedure cannot be said about other parameters

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which does not show any order (Kamerbaev, 2001). Based on the acquired knowledge about the value of moisture binding enthalpy by article authors was developed the technology of meat-vegetable products from sub- products and vegetable raw materials with regression hydration technologies. To determine the shelf life of the product has also been identified moisture activity of food. The indicator "moisture activity" is an important tool in the development of technological processes and production as well as ensures high quality and extends shelf life of food products.

All natural foods contain moisture in their composition in varying amounts of their states, from this largely depends on their technological properties and shelf life. In our country for the characteristics of the moisture content of a single indicator is used in food products is "the mass fraction of moisture" or product humidity. This quantitative measure does not reflect all the complex interactions that are present in the food product and to which is moisture. However, there is a figure "moisture activity" which is the main criterion of the characteristics of the state of moisture in foods and is widely used around the world as to predict the technological properties of the products and is a powerful quality control tool for the food and its shelf life (Gustavo *et al*., 2007; Ginzburg *et al*., 1990; Leistner, 2006).

MATERIALS AND METHODS

Polanyi-Rebinder equation used to calculate the energy of hydrogen bond and the enthalpy of hydrogen bond was calculated with the equation provided by researcher (Kamerbaev, 2001). The energy consumed to remove 1 kg mole^{-1} of water from wet material is determined by Eq. 1:

$$A = -RT\ln\varphi \quad (1)$$

Where:

A = Moisture binding energy (J mole^{-1})
R = Universal gas constant (J/(mole×K))
T = Temperature (°C)
φ = Relative humidity

$$I_{CB} = L \cdot m = -RT\ln a_w \cdot m_{moisture}, \text{ J} \quad (2)$$

Where:

L = Moisture bonding energy (J kg^{-1})
R = Gas constant
a_w = Moisture activity
m = Mass of moisture

$$I_{CB} = Lm_w \quad (3)$$

Here, m_w is weight of moisture which was calculated with Eq. 4:

$$M_w = W\, m_{product} \quad (4)$$

Moisture activity was examined by AquaLab (USA) and the equipment developed by academics I.A. Rogov and U.Ch. Chomanov, the method of determining the moisture activity at the Rogov-Chomanov equipment is as follows; in a flask No. 2 placed examined product, the flask No. 6 is filled with distilled moisture. After fixing the flasks at the equipment with opened valves No. 4 the air is pumped from the equipment by vacuum pump No. 8. The duration of pumping is 5 min. Then, valves are closed and after 6-8 min fluid movement stops in manometer. The manometers indication ΔP is the difference between the equilibrium vapor pressure of moisture over distilled moisture P_0 and equilibrium pressure of moisture vapor over the product P_{pr}, i.e.:

$$\Delta P = P_0 - P_{pr} \quad (5)$$

The moisture activity value is calculated by Eq. 6:

$$a_w = \frac{P_0 - \Delta P}{P_0} \quad (6)$$

The examination of moisture content in product was performed in Evlas 2M (Russia). Determination of the amino acid, fatty acid, vitamin and mineral composition of the meat mass spectrometer ion cyclotron resonance Fourier transform (Germany) and Gas Chromatograph Shimadzu GC-Series 2010 and Series liquid chromatograph Shimadzu LC-2010 (Japan) (Toldra, 2010).

RESULTS AND DISCUSSION

In the laboratory of technology for the processing of animal products were developed meat-plant product technology from sub-products as liver, heart, kidneys and brains and beef vegetable raw carrots, pumpkin, beets, potatoes and onions. During the technological mixing process of the products physical and thermodynamic parameters of each product were investigated to determine the order of mixing for the regression-hydration technology (Table 1).

The binding of moisture with a substance is characterized by free energy of is thermic dehydration which is kind of a work required to remove1 mole of water at the constant temperature with no changes in substance content at this moisture content. If there is a free moisture in a substance alt. During the removal of moisture the

Table 1: The main characteristics of additives

Names	Humidity (W, %)	Weight of additives ($m \cdot 10^3$.kg)	Moisture content (m_w, kg)	Moisture activity (a_w)	Energy of hydrogen bond (L, kJ kg^{-1})	Enthalpy of hydrogen bond (I_{CB}, kJ)
Liver	26.7	50	1.335	0.61	70.34	93.900
Heart	32.3	5	0.1625	0.65	61.37	9.970
Kidney	35.5	5	0.1775	0.66	59.09	10.480
Brain	33.3	5	0.1665	0.64	63.50	10.570
Carrot	31.4	5	0.157	0.72	46.70	7.330
Pumpkin	40.8	5	0.204	0.73	44.71	9.120
Potato	34.1	5	0.1705	0.69	52.82	9.001
Beet	31.2	5	0.156	0.71	48.70	7.590
Onion	30.8	5	0.154	0.70	50.69	7.800
Rice bran	10.2	10	0.102	0.45	113.63	11.590

Table 2: The experimental procedure

	The order of mixing of additives											
Methods No.	1	2	3	4	5	6	7	8	9	10	Moisture activity	Enthalpy of hydrogen bond (I_{CB}, kJ)
1	I	II	III	IV	V	VI	VII	VIII	IX	X	0.645	5900
2	II	III	I	VI	V	VII	VIII	IV	X	IX	0.656	6000
3	X	IX	VIII	VII	VI	V	IV	III	II	I	0.652	6112
4	I	X	IV	II	III	VII	IX	VIII	V	VI	0.648	6200
5	V	II	III	VI	IV	I	VII	VIII	IX	X	0.651	5923
6	Initial										0.864	5645

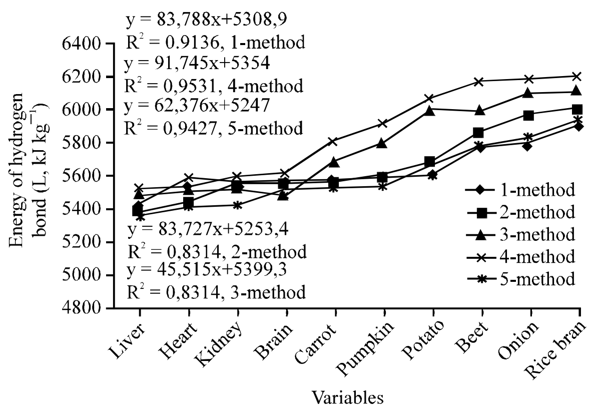

Fig. 1: The changes in enthalpy of hydrogen bond by adding additives

strength of its bond with a material is growing and the energy of binding alt is growing too. The lower the moisture content of the material, the greater the value of the binding energy. Based on regression-hydration technology products were mixed.

The experimental studies were performed as it is shown below; the temperature of the products: -293 K, all ingredients were mixed for 1 min, the rotation speed was 1200 rpm. As a target function the enthalpy of hydrogen bond and moisture activity indexes were taken (Fig. 1). The mixing procedure of performed experimental studies is displayed in Table 2. The experimental matrix designed to avoid repeat in each method. Each experiment was compared with initial product. The examination method was able to perform by the putting and mixing of all components in the one time. In the matrix roman digits means; 1-liver, 2-heart, 3-kidney, 4-brain, 5-carrot, 6-pumpkin, 7-potato, 8-beet, 9-onion, 10-rice bran.

During the studies the best result was seen in 4th method which is according to hydration order. Means that, the order of mixing is as: liver→rice bran→brain→kidney→heart→pumpkin→potato→onion→be et→carrot (Fig. 2). As it shown in domestic and foreign literature, 100 g of meat products should provide by 20, 25% of proteins, fats, etc. for one day the necessary food items. During the production complex products from sub products the chemical composition of the heat-treated products as liver, kidney, heart and brain was identified. The chemical composition is given in Table 3.

By the adding sub-products in 4 different ratios production of various products were examined (Table 4-7). The products quality, color, taste, smell, texture and appearance change was evaluated. Organoleptic control of initial and experimental versions evaluated in 5-point scale.

Numerous studies have shown that as a result of the combined ratio 50×20×20×10 products compared with initial received the highest scores. Use of vegetables addition changes nutritional value, organoleptic characteristics. During the study various vegetables organoleptic characteristics were identified (Table 8-11). As vegetable carrot, squash, beet, potato, onion and rice bran are used. According to literary to meat products vegetables added up to 25-30%. For this reason, during the research amount of vegetables were as following; experiment 1-20% and share of each vegetable 4%, experiment 2-25% and share of each vegetable 5%, experiment 3-30% and share of each vegetable 6% and rice

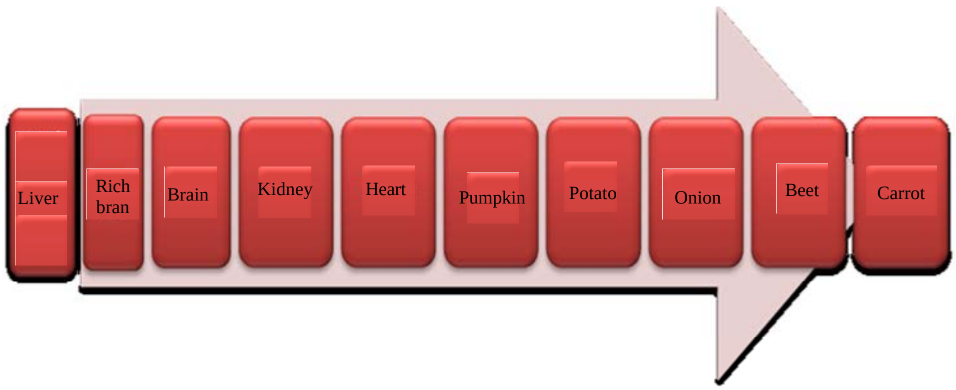

Fig. 2: The mixing order of additives

Table 3: Chemical composition of heat-treated sub-products

	Content (%)				
Name	Moisture	Protein	Fat	Carbohydrate	Ash
Liver	26.7	37.7	10.2	16.93	6.47
Heart	32.3	36.5	9.8	14.84	6.56
Kidney	35.5	35.0	10.2	14.25	5.05
Brain	33.3	34.2	11.3	13.33	7.87

Table 4: The ratios of sub-products during the making of liver-based product formulations (%)

		I-Liver-based (%)				
Version	Control (%)	Liver	Heart	Kidney	Brain	Organoleptic evaluation (total evaluation)
Initial	100					4.3
Experiment 1		70	10	10	10	4.2
Experiment 2		60	15	15	10	4.3
Experiment 3		50	20	20	10	4.4
Experiment 4		40	25	25	10	4.3

Table 5: The ratios of sub-products during the making of heart-based product formulations (%)

		II-Heart-based (%)				
Version	Control (%)	Liver	Heart	Kidney	Brain	Organoleptic evaluation (total evaluation)
Control	100					4.3
Experiment 1		10	70	10	10	4.2
Experiment 2		15	60	15	10	4.3
Experiment 3		20	50	20	10	4.4
Experiment 4		25	40	25	10	4.3

Table 6: The ratios of sub-products during the making of kidney-based product formulations (%)

		II-Heart-based (%)				
Version	Control (%)	Liver	Heart	Kidney	Brain	Organoleptic evaluation (total evaluation)
Control	100					4.3
Experiment 1		10	10	70	10	4.2
Experiment 2		15	15	60	10	4.3
Experiment 3		20	20	50	10	4.4
Experiment 4		25	25	40	10	4.3

Table 7: The ratios of sub-products during the making of brain-based product formulations (%)

		II-Heart-based (%)				
Version	Control (%)	Liver	Heart	Kidney	Brain	Organoleptic evaluation (total evaluation)
Control	100					4.3
Experiment 1		10	10	10	70	4.3
Experiment 2		15	15	10	60	4.3
Experiment 3		20	20	10	50	4.4
Experiment 4		25	25	10	40	4.3

Table 8: Organoleptic properties of vegetable additives added I-liver based products

I-Liver-based products	Volume of vegetable additives (%)	Rice bran (%)	Organoleptic evaluation			
			Color	Taste and smell	Consistency	Total grade
Control	-	Without additives	4.36	4.46	4.43	4.43
Experiment 1	20	15	4.36	4.46	4.43	4.43
Experiment 2	25	10	4.46	4.56	4.53	4.56
Experiment 3	30	5	4.43	4.46	4.46	4.46

Table 9: Organoleptic properties of vegetable additives added II-heart based products

II-Heart-based products	Volume of vegetable additives (%)	Rice bran (%)	Organoleptic evaluation			
			Color	Taste and smell	Consistency	Total grade
Control	-	-	4.33	4.33	4.33	4.33
Experiment 1	20	15	4.33	4.33	4.33	4.33
Experiment 2	25	10	4.46	4.56	4.66	4.56
Experiment 3	30	5	4.43	4.46	4465	4.46

Table 10: Organoleptic properties of vegetable additives added III -kidney -based products

III-kidney-based products	Volume of vegetable additives (%)	Rice bran (%)	Organoleptic evaluation			
			Color	Taste and smell	Consistency	Total grade
Control	-	-	4.43	4.46	4.43	4.43
Experiment 1	20	15	4.43	4.46	4.46	4.46
Experiment 2	25	10	4.46	4.56	4.56	4.56
Experiment 3	30	5	4.43	4.46	4.46	4.43

Table 11: Organoleptic properties of vegetable additives added brain IV -based products

IV-Brain-based products	Volume of vegetable additives (%)	Rice bran (%)	Organoleptic evaluation			
			Color	Taste and smell	Consistency	Total grade
Control	-	-	4.43	4.46	4.43	4.43
Experiment 1	20	15	4.43	4.46	4.46	4.46
Experiment 2	25	10	4.46	4.56	4.56	4.56
Experiment 3	30	5	4.43	4.46	4.43	4.43

Table 12: Formulations of finished products

Names of products	I-liver-based	II-heart-based	III-kidney-based	IV-brain-based
Sub-products (%), Total number	65	65	65	65
Carrot	5	5	5	5
Pumpkin	5	5	5	5
Beet	5	5	5	5
Potato	5	5	5	5
Onion	5	5	5	5
Rice bran	10	10	10	10
Total	100	100	100	100
Spices (g kg^{-1}) black pepper	0.1	0.1	0.1	0.1
Salt	0.2	0.2	0.2	0.2

Table 13: Chemical content of finished products

Indicators	Control	I-liver-based	II-heart-based	III-kidney-based	IV-brain-based
Protein (g/100 g)	14.3	39.38	36.93	35.70	27.93
Fat	9.7	10.08	9.45	8.17	23.68
Carbohydrates (g)	16.3	17.05	14.96	14.86	13.74
Moisture (g)	55.0	29.49	34.17	36.42	29.23
Energy value	275.0	316.00	293.00	276.00	380.00

bran in ratio of 15, 10 and 5%. When vegetables added up to 30% the taste and odor reduction in byproducts were seen. The best results of organoleptic characteristics have been shown in experiment 2 with ratio of 65:25:10, sub-products-65%, vegetables-25% and rice bran-10%. Price is not a mixture of products derived from plant foods than organoleptic taste, appearance and consistency are different. The products had an average of 4.56 points in the study. According to performed studies results it was concluded that the average ratios of components were presented. The ratios of sub-products and vegetable additives were changed in 4 different formulations (Table 12). Enriched with vegetable additives subproducts has shown high results in terms of taste harmony. The finished products of physico-chemical parameters are shown in Table 13. Analysis of the data characterizing the

Table 14: Vitamine and mineral content of finished products, in 100g of product

	Names of products				
Indicators	Control	I-liver-based	II-heart-based	III-kidney-based	IV-brain-based
A (mcg)	4236	5343	442	561	423
B_1 (mg)	0.18	0.21	0.25	0.26	0.09
B2, (mg)	0.25	1. 49	0.51	1.21	1.12
C (mg)	12.2	22.3	2.6	6.5	1.9
E (mg)	0.45	0.65	0.38	0.51	0.25
β-carotene (mcg)	400	650	9	45.5	8
PP (mg)	5.32	6.06	3.46	3.85	2.14
P. mg	246.42	386	317	332	373
Zn (mcg)	2678	3685	2745	2845	3395
Mg (mg)	78	87	88	85	84
Fe (mcg)	12356	13295	5590	6170	4495
Mn (mcg)	1956	2124	2020	2060	2003

Table 15: Amino acid content of finished products

	Names of products				
Indicators	Control	I-liver-based	II-heart-based	III-kidney-based	IV-brain-based
Essential amino acid (mg/100g)	6435	15919	14913	13971	10247
Valine	986	2606	2078	2057	1381
Isoleucine	781	1935	1912	1714	1253
Leucine	1123	3332	3212	2977	2226
Lysine	1214	2995	3100	2769	1931
Methionine	396	915	876	783	533
Threonine	785	1697	1689	1533	1239
Tryptophan	356	497	505	512	377
Phenylalanine	794	1940	1542	1626	1306

Table 16: Fatty acid content of finished products

	Names of products				
Indicators	Control	I-liver-based	II-heart-based	III-kidney-based	IV-brain-based
Fatty acid (mg/100^{-1}) gsaturated included:	1.23	3.49	2.08	2.24	7.82
C14:0 myristic	0.02	0.05	0.06	0.03	0.21
C16:0 palmitic	0.36	1.23	0.97	1.27	3.94
C18:0 stearic acid	0.85	2.21	1.05	0.94	3.67
Monounsaturated included	0.69	1.91	2.66	1.78	7.46
C16:1 palmitoleic	0.07	0.14	0.42	0.24	0.55
C18:1 leic	0.62	1.77	2.44	1.54	6.91
Polyunsaturated included	1.77	2.01	2.47	2.26	2.79
C18:2 linoleic	1.02	1.14	1.87	1.63	0.39
C18:3 linoelaidic	0.08	0.15	0.03	0.09	0.49
C20;4 rachidonic	0.67	0.72	0.57	0.54	1.91
Fatty acid content	2.81	7.41	7.21	6.28	18.07

overall chemical composition of meat and vegetable products indicates that it has a high protein content from 27.93-39.38 g which defines the high potential and the use of sub-products of vegetable raw materials provided mutually balancing of the components in the formulation. The nutritional and biological evaluation of examined products were determined (Table 14-16). The biological value of the product is characterized by the amount of biologically active substances: amino acids, vitamins, macro and micronutrients, essential polyunsaturated fatty acids.

As a result of studies, higher amounts of vitamins, vitamin C-22.3-6.5 mg/100 g^2 of vitamin B6-1.49-1.21 mg/100 g liver and kidney-based products and beta carotene -9-8 mg/100 g^2 the heart and the brain-based product, vitamin PP 6.06-3.85 mg/100 g of the product is determined on liver-based and the kidney-based products.

As a result of studies, a lot of phosphorus, 373 mg/100 g^2 brain-based product, the amount of iron 13295-6170 mg/100 g^2 of the product based on the liver and kidneys, magnesium 88 mg/100 g^2 of the product is determined on the heart-based product. As a result of research in the composition of the amino acids essential amino acids quantitative 15919-14913 mg/100 g^2 liver and heart based products to be high compared to the initial. As a result of research C18:2 linolenic 1.87 mg 100 g^2 of the heart-based product, C18:3 linolenic 0.49 mg 100 g^2 in brain-based products determined to be high.

Table 17: Stability card of food products

Resistance group of products during the storage	Indicators a_w	pH	Storage Temperature (T°C)
A (fastly perishable)	>0.95	>5.2	5
B (perishable)	0.91-0.96	5.0-5.2	10
C (persistent long-term storage)	<0.9 <0.91	<5.2 <5.0	Refrigeration is not required

In this regard, during the research the nutritional and biological value of vegetables enriched sub-products proved to be as valuable products. Issues related to the preservation of the quality and the reduction of food losses in their long-term storage is one of the most important tasks facing the workers of processing industry. Solving the problem requires a detailed study of the influence of external factors (ambient temperature, relative humidity, etc.) to change the quality parameters of food products. At the present time it has not yet developed a common methodology to determine the shelf life of food products while the shelf life of the product is one of the major determinants of technological parameters. Despite the fact that today a number of known works and studies to determine the dependence of the shelf life of food products by individual groups of parameters it is still a problem.

Analysis and synthesis domestic and foreign research data shows that in assessing the status of the product should be resorted to when harenenii integral parameters, the most informative of which is the "moisture activity". With this in mind, we have conducted a number of research projects aimed at predicting the shelf life of food products, the results of which would allow to forecast with greater accuracy.

In our case, we represent the period of storage as a function of several variables. Since, many researchers previously found that among this essential parameters for determining the shelf life of foods and include setting the pH, the study of the extent of its impact on the life ihraneniya is very important. Analysis of the results of the experimental data shows that in the pH range from 5.0-7.0 at a value of aw >0.91 significantly affects the duration of the storage life of the product.

Thermodynamic properties (moisture activity and moisture content) of 4 products based on liver, heart, kidney and brain were determined. The results showed that the heat-treated meat products in the moisture activity is reduced to aw = 0.65, pH of 4.9-5.0 which allows you to assign them to the group "C" <0.91 for the "stability card" (19,20), i.e., to products stable under prolonged storage (Table 17).

CONCLUSION

As a result it was proposed sub-products meat products technology with the addition of vegetable raw materials and the use of regression-hydration technique. Proteins are composed of sausage products were characterized by balance of essential amino acids, the total content of which exceeds the same indicator for the perfect protein. As a result of studies, proteins content in developed products were characterized by balance of essential amino acids, the total content of which exceeds the same indicator for the control. Higher amounts of vitamins of B, C, B6 were seen in the liver and kidney based products and beta carotene in the heart and brain-based products, vitamin PP in the products based on liver and kidney. The content of mineral substances in the developed products (mg/g^2); iron-4.2, zinc-5.6, phosphorus-151.52, magnesium-34.5, calcium-10.7. Taking into account the per diem rate of trace elements for human consumption 100 g combined sub-product satisfies the need for iron in 25-30%, zinc in 25-30%, phosphorus in 10-12% and magnesium in 8-10%.

REFERENCES

Ginzburg, A.C., M.A. Gromov and G.I. Krasouskaya, 1990. Thermal Characteristics of Foods: A Handbook. Agropromizdat, Moscow, Russia, Pages: 287.

Gustavo, V.B.C., J.F.J. Anthony, J.S. Shelly and P.L. Theodore, 2007. Water Activity in Foods: Fundamentals and Applications. Wiley-Blackwell, Hoboken, New Jersey, USA., ISBN:9780813824086, Pages: 440.

Kamerbaev, A.Y., 2001. The Role of Moisture in Food Products and its Function. Monograph Publisher, Almaty, Kazakhstan, Pages: 203.

Leistner, L., 2006. Barrier technologies: Combined treatment methods to ensure the stability, safety and quality of food. Institute of Meat Industry. Geneva, Switzerland.

Toldra, F., 2010. Handbook of Meat Processing. Wiley-Blackwell, Hoboken, New Jersey, USA., ISBN:978-0-8138-2182-5, Pages: 566.