Journal of International Scientific Publications: Agriculture and Food

Volume 2, ISSN 1314-8591 (Online), Published at: http://www.scientific-publications.net

QUALITY FEATURES OF MEAT PRODUCTS WITH THE ADDITION OF MODIFIED STARCHES

Marek Cierach[1], Natalia Idaszewska[2], Jacek Niedźwiedź[1]

[1] Department of Meat Technology and Chemistry, University of Warmia and Mazury in Olsztyn,

Ul. Oczapowskiego 2, 10-719 Olsztyn, Poland

[2] Institute of Machines and Motor Vehicles, Poznan University of Technology,

Ul. Piotrowo 3, 60-965 Poznan, Poland

Abstract

The aim of this research was to conduct comparative study of meat products with the addition of four different modified starches with a high degree of cross-linking. Finely-grind meat blocks were used as research material. It was demonstrated that the addition of starch resulted in a significant improvement in hydration properties of meat batters. Also cooking loss and purge during storage of the final product was reduced. These changes resulted in improvement of texture, juiciness and colour of meat products. Improvement of colour stability of these products suggests the occurrence of protective effect of starch on nitrosohemochrome.

Key words: *modified starches, meat products, texture, colour*

1. INTRODUCTION

The development of modern meat processing technology, commitment of quality and final product standard enforce the use of modern, efficient, but also completely safe for health functional additives. Quality requirements applied to the meat products are referred also to provide permanent, unchanging in time, desired sensory characteristics at each stage of production, distribution and storage – "shelf life". There are many types of additives used and recommended for meat products. Previously, they were used mainly as substitutes of meat protein. However, now the most important are their functional properties, particularly the formation and maintenance of desired texture. Awareness of the importance of texture in creating meat products acceptability by consumers was confirmed in many of the studies of consumer preferences. Therefore functional additives are currently of prime importance for modulating texture of meat products (Claus and Hunt, 1991; Carballo et al., 1995; Fernandez et al., 1996; Tederko, 1998; Cierach, 2002; Li and Yeh, 2003). For several years there has been increased interest of technologists in native and modified hydrocolloids derived from plants and animals which are involved in formation of meat products texture. The addition of these substances have a decisive impact on:

- increase water binding as a result of formation of network structure, which reduces cooking losses, aggregation of jelly, improves texture, juiciness and flavour of the product,
- stabilization of meat batter emulsion, fat emulsification,
- improvement of the degree of individual components binding of raw batters small and medium ground, resulting in improvement of appearance, bind strength of slice, slicing; it allows to increase the number of types of sliced meat products.
- thickening and stabilization of sauces, jellies, marinades occurring in many meat products (Yang et al., 1995; Cegiełka, 2008; Abbas et al., 2010; Schube, 2013).

Starches belong to the group of additives influencing texture. They are recognized in a small extent and used by the meat industry. Starch is a polysaccharide produced by most of green plants as an energy store. It is deposited in the form of grains whose size and shape depends on the type of plant. The main component of each starch molecule is sugar d-glucose. In aqueous solutions, d-glucose is not very stable and is converted to the two cyclic forms: α-d-glucose and β-d-glucose. These rings are able to form a connection between them which result in the formation of chains of different length. Bound molecules of α-d-glucose form amylose, while molecules of β-d-glucose form cellulose. In addition to binding molecules by 1,4-α (β)-glycosidic bounds, it is possible for α-glucose molecule binding by α-1,6-glycosidic bounds. There are formed branched molecules and particular branch has a shorter chain – such structure has amylopectin. Amylose and amylopectin are basic components of starch. Amylose consists of linear molecules forming helical structure. Amylopectin contains a large number of

branches arranged in the helical form. Generally, amylose content in starch is 15-25% and amylopectin 75-85%. The greater part of amylopectin in starch, the greater stability of an aqueous solution. Amylose easily precipitates out of solution and amylopectin gives a stable solution (Blazek and Copeland, 2008). Native starch creates gruel, which viscosity depends on origin of species. A major drawback of starch is the lack of stability of produced gruel. The viscosity of the starch solution changes with time due to temperature, mixing and reduced or increased pH. Clear hot solutions of native starch after reaching and creating gel, rapidly retrograde, which is reflected by gruel turbidity (Sandhu and Singh, 2007; Sobolewska-Zielińska and Fortuna, 2010; Neelam et al., 2012).

The gel formation is the result of the fact that during heat treatment short sections of amylose are arranged very tightly among themselves. Water that has been stored between the chains during this process is removed. This process is known as retrogradation, and the effect of pressing water – syneresis. For this reason, native starches have limited application and very often make it impossible to obtain specific finished products (Fortuna et al., 2004). Therefore, numerous methods of starch modification are used to adjust them to the technological processes in order to ensure creation of a particular form or consistency and good quality as well as stability of the product during storage (Meschi, 1997; Walkowski and Lewandowicz, 2004; Mitrus and Wójtowicz, 2011). The most important types of starch modification is cross-linking and stabilizing. Cross-linking enhances already existing hydrogen bridges between starch chains by the addition of additional bridges. Starch which was formed in this way is more thermally and mechanically resistant. As a result, cross-linked starch in the identical technological processes maintains the same form and properties, while native starch disintegrates. Cross-linking of starch increases its resistance, solubility in cold water or contributes to the formation of fine-crystalline starch and influences tenderness of products (Neelam et al., 2012). Actually scientific data, relating to the use of modified starches as a component of meat products, indicate high safety for their use without adverse effect on consumers health (Walkowski and Lewandowicz, 2004; Krysińska et al., 2008).

It has been shown in a number of studies that modified starches provide many beneficial technological effects and should be used more widely by the meat industry. However doses of starch must be consistent with current recommendations for health and nutrition. Consumption of modified starches does not affect consumer health because they are readily metabolized. Recently, more and more attention is paid to the rational nutrition and production of food with reduced fat content. The use of modified starch for the production of meat products makes it possible to better balance the diet of consumers by broadening the market offer of products with a reduced-calorie (Jimenez-Colmenero et al., 1996; Hughes et al., 1998; Chung et al., 2008; Vongsawasdi et al., 2008).

2. MATERIALS AND METHODS

The raw material for the production of meat batters and meat products was pork shoulder with a fat content of about 20%, obtained 24 hours after slaughter of pigs (Polish Large White breed with a mass of about 100 kg). Chilled meat to a temperature of about 4°C was grounded (Ø 3mm) and next 2.8% of curing mix was added (99.4% of salt and 0.6% of sodium nitrate (III)). The mixture of meat and curing mix was kept at about 4°C for 3 h and then mixed with ice water (30%). To the obtained meat batters 3% of starch was added based on the weight of the hydrated batter. The following starch preparations were used as functional additives:

- acetylated distarch adipate (adamyl; E1422),
- monostarch phosphate (skronet; E1410),
- acetylated distarch adipate with a high degree of cross-linking (adanet; E1422),
- acetylated distarch phosphate (fremix; E1414).

The aim of preliminary stage of the experiment was to analyse selected properties of modified starches. pH value of 10% aqueous suspensions of modified starches were measured using an ion-meter WTW, Type pH340/ION-SET equipped with combined electrode with integrated temperature sensor, Type SenTix 21 (Krełowska-Kułas, 1993).

The water content in the starch preparation was determined by drying method at 105±1°C (Krełowska-Kułas, 1993).

Amount of cooking loss was assessed as the weight loss of meat product sample during cooking at 75°C (Pan and Singh, 2001), according to the formula:

$$C = \frac{(a-b)}{a} * 100\%$$

where:

C – amount of cooking loss (%),

a – weight of sample before heat treatment (g),

b – weight of sample after heat treatment (g).

Then the viscosity of 5% aqueous suspensions of starch has been studied depending on the temperature. The values were recorded by Brabender Amylograph (model 800145) with electronic control of temperature. Amylograph curves were analysed according to ICC Standard No. 126.

Texture parameters were determined using texture analyser TA-XT2i/25 and computer software Texture Exspert Exceed. Dimensions of samples were 10x10x10 mm. Samples of model product were placed between two parallel plates: a flat plate from the bottom and movable piston from the top. The piston moving speed was 200 mm/s, which resulted in double compression of the sample to 50% of the original height. The time distance between first and second compression was 60 seconds (Man et al., 1975; Bourne, 1982, 1997; Klettner, 1994; Giese, 1995; Cierach and Majewska, 1997).

Colour parameters were measured on the surface of the cross-section of the meat product using spectrophotometer, Dr. Lange with spectral-C software. Color parameters were presented in the CIE (L*a*b*) system. Cross-section of meat product was exposed to daylight for 0.5, 1, 2, and 3 h in order to determine colour stability (Clydesdale, 1978; Van Oeckel et al., 1999; Cierach and Paulo, 2000).

Obtained results were statistically analysed using STATISTICA 10.0 PL. The significance of differences between the average values at $p<0.05$ were determined using the Duncan's Multiple-Range test.

3. RESULTS AND DISCUSSION

The initial stage of research was to characterize some of the properties of starch preparations, significant in terms of their function to bind and retain water in meat products.

The pH value of the 3% aqueous suspension of starch was from 5.20 for adamyl to 7.52 for skronet (Table 1). Considering the fact that the isoelectric point of the myosin is at a level of about pH = 5.4, the starch suspensions which have pH greater than 5.4 may increase water holding capacity of meat (meat batter) by direct influence on the pH of the environment. This applies especially to skronet suspension, which was characterized by the pH value of 7.52. The lowest pH value was noted for adamyl (Table 1).

Water content of the starch preparations ranged from 7.94% (fremix) to 14.72% (adamyl). All preparations of starch were characterized by the moisture content below 20%, which is consistent with the technical requirements for this type of additives (Table 1).

Table 1. Characteristics of starch preparations and their impact on the amount of cooking loss of meat products.

Sample	pH value	Water content (%)	Cooking loss (%)
Control	-	-	25,14[a]
Adamyl	5,20[a]	14,72[a]	16,05[b]
Fremix	5,83[b]	7,94[b]	14,25[c]
Adanet	6,02[b]	12,70[c]	16,84[b]
Skronet	7,52[c]	12,97[c]	12,58[d]

[a, b, c, …] – means in a column with the same superscript letter are not different ($p<0.05$).

Volume 2, ISSN 1314-8591 (Online), Published at: http://www.scientific-publications.net

It has been shown that the addition of modified starch to meat products increased water-holding capacity of emulsion consisting of fat, proteins and water during heat treatment to the temperature of about 75°C. The amount of cooking loss of meat products without the addition of modified starch was about 25%. The addition of starch preparations decreased cooking loss to 12-17%. The greatest water binding effect showed skronet. The lowest cooking loss was 12.58%, which was twice lower in comparison with the control sample (Table 1). These advantageous properties of starch phosphate were described by Lewandowicz et al., (1999). Heat treatment at the temperature at which myofibrillar proteins were denatured and starch has undergone gelatinization, resulted in a significant decrease of cooking losses.

Analysis of changes of the viscosity of tested starches during heat treatment showed that the increase of suspensions viscosity began in the temperature between 55 to 65°C (Figure 1). Among the modified starches the greatest viscosity in the temperature characteristic for the heat treatment of meat products had skronet. The other starches showed twice lower viscosity of suspensions. Gelatinization of starch and properties of the gel are essential for the proper use of starch in a particular meat product or other food products. The functionality of the starch is strongly inducible by the presence of sugars in food (Gunaratne et al., 2007; Abbas et al., 2010).

During heat treatment at the temperature of about 75°C the viscosity of skronet suspension was 1400 BU and the remaining starches did not exceed 1000 BU (Figure 1). Gelatinization strength of skronet loss in the greatest extent decreased amount of cooking (Table 1). When the temperature of heat treatment of starches suspensions exceeds 75°C and reached 95°C, it was founded that the viscosity of skronet increased strongly to over 2000 BU. The viscosity of the other starches suspensions stabilized at a similar level (Figure 1). This fact indicates that skronet can be used in meat products subjected to heat treatment at relatively high temperature and its functionality to binding and retaining water improves as the temperature rises (Lewandowicz et al., 1999).

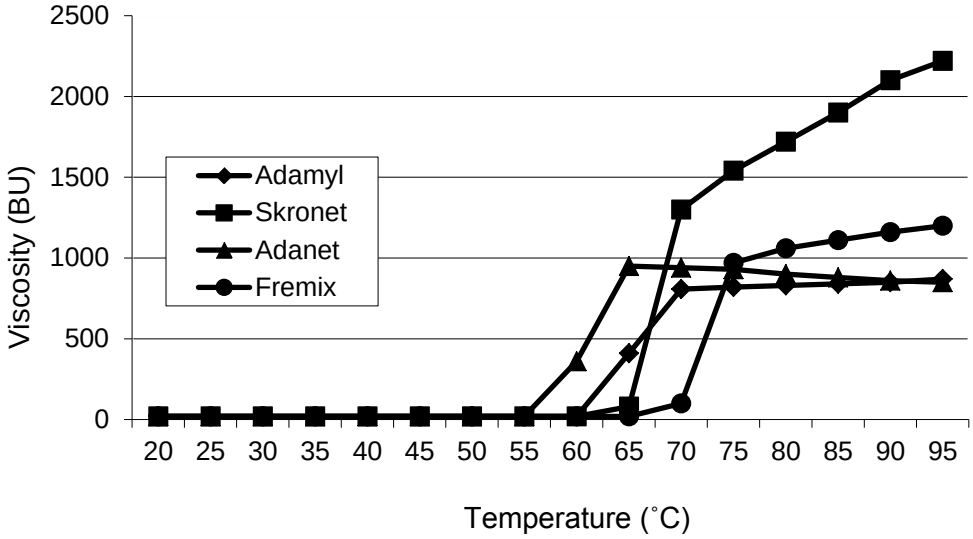

Figure 1. Changes in viscosity of the 5% suspension of starch in water depending on the temperature

Modified starches with high gelatinization strength in a wide range of temperature usually have a reduced ability to retrogradatio and syneresis. It should be taken into account that the ability to retrogradation in model suspensions may be different than in meat batters, where the non-starch components interact (salts, lipids, saccharides, acids, hydrocolloids) (Sandhu and Singh, 2007; Sobolewska-Zielińska and Fortuna, 2010).

Reduction of the amount of cooking loss due to the use of modified starch had a significant impact on the texture and colour of the tested meat products. Texture profile analysis (test TPA) allowed to determine the texture parameters, such as: first hardness (T1), the second hardness (T2), adhesiveness (E), Cohesiveness (S), gumminess (G) and Chewiness (P). Hardness (T1) of tested meat blocks ranged from 20.00 to 20.67 N (control sample: 23.33N) and the hardness (T2) respectively in the range from 14.33 to 17.00 N (control sample 13.33 N) (Table 2). The results showed that the addition of starch resulted in a decrease of hardness (T1) and the increase of hardness (T2) when compared with the products without the addition of starch. Products with the addition of starches, which limited the amount of cooking loss, also affected the reduction of hardness (T1) and increased hardness (T2). Texture of products with the addition of starches (starches which effectively reduced amount of

Volume 2, ISSN 1314-8591 (Online), Published at: http://www.scientific-publications.net

cooking loss) were characterized by lower cohesiveness, gumminess and chewiness. The addition of modified starches decreased cohesiveness from 0.41 to about 0.30 unit, gumminess from about 9.5 to about 6 units and chewiness from about 25 to about 20-21 units (Table 2). The largest differences in the texture of meat blocks indicate that a high degree of hydration and the effect of the starches may vary texture parameters to a great extent. Similar trends were obtained by other authors studying the effect of starches on the texture of foods including meat products, which emphasize the importance of the amount of cooking loss and chemical composition of batter (Kong et al., 1999; Pietrasik, 1999; Li and Yeh, 2003; Dzieszuk et al., 2005).

Very interesting results were obtained by examining the colour of meat products with the addition of starches and in particular its stability during exposure to the light. The colour is a function of the set of raw meat, fat and other additives included into the batter, which differ in dominant wavelength, colorimetric purity and photometric brightness. Very important is also amount of water, which affects the dynamics of occurring changes and thus technologically modulates the colour quality and stability.

Table 2. Texture parameters of meat blocks with the addition of modified starch

Sample	Texture parameters					
	Hardness 1 (N)	Hardness 2 (N)	Cohesiveness	Adhesiveness	Gumminess	Chewiness
Control	23,33^{a}	13,33^{a}	0,41^{a}	3,67^{a}	9,56^{a}	35,10^{a}
Adamyl	20,67^{b}	14,33^{a}	0,30^{b}	3,52^{ab}	6,20^{b}	21,83^{b}
Skronet	20,67^{b}	16,67^{b}	0,28^{b}	3,48^{ab}	5,79^{b}	20,14^{b}
Adanet	20,00^{b}	17,00^{b}	0,31^{b}	3,40^{b}	6,20^{b}	21,08^{b}
Fremix	20,67^{b}	16,00^{b}	0,29^{b}	3,35^{b}	5,99^{b}	20,08^{b}

$^{a, b, c}$ – means in a column with the same superscript letter are not different ($p<0.05$).

The cross-sections of experimental meat blocks were characterized by an increase of colour lightness L*=47.26 (control product without the addition of starch) to approximately L*=51for products with the addition of starches (Table 3).

Table 3. Colour lightness (L*) of meat blocks with the addition of modified starches during exposure

Sample	Exposure time (h)				
	0	0,5	1	2	3
Control	47,26^{aA}	46,45^{aAB}	46,12^{aB}	45,78^{aBC}	45,12^{aC}
Adamyl	50,48^{bA}	49,68^{bAB}	49,15^{bB}	48,75^{bB}	48,99^{bB}
Skronet	51,23^{bA}	51,02^{bA}	50,41^{bA}	48,79^{bB}	48,11^{bB}
Adanet	51,01^{bA}	50,23^{bA}	50,68^{bA}	49,18^{bB}	48,85^{bB}
Fremix	51,40^{bA}	50,45^{bA}	50,43^{bA}	49,25^{bB}	49,15^{bB}

$^{a, b}$ – means in a column with the same superscript letter are not different ($p<0.05$).

$^{A, B, C}$ – means in a row with the same superscript letter are not different ($p<0.05$).

Experimental meat blocks were characterized by reduced redness in more than 2 units. Redness of control block cross-section was a*=8.33 and the samples with the addition of modified starch from 5.89 to 6.23 (Table 4).

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Table 4. Colour redness (a*) of meat blocks with the addition of modified starches during exposure

Sample	Exposure time (h)				
	0	0,5	1	2	3
Control	$8,33^{aA}$	$7,21^{aB}$	$5,48^{aC}$	$4,61^{aC}$	$3,58^{aD}$
Adamyl	$6,15^{bA}$	$5,15^{bB}$	$4,21^{bBC}$	$3,89^{bC}$	$3,68^{aC}$
Skronet	$5,89^{bA}$	$5,14b^{AB}$	$4,90^{acB}$	$4,32^{acBC}$	$3,52^{aC}$
Adanet	$6,23^{bA}$	$5,08^{bB}$	$4,61^{bcBC}$	$4,12^{bcBC}$	$3,87^{aC}$
Fremix	$6,14^{bA}$	$4,95^{bB}$	$4,65^{bcBC}$	$3,88^{bcC}$	$3,70^{aC}$

$^{a, b, c}$ – means in a column with the same superscript letter are not different ($p<0.05$).

$^{A, B, C, \dots}$ – means in a row with the same superscript letter are not different ($p<0.05$).

Colour yellowness of the control and experimental products ranged from 14.12 to 15.06. The addition of starches resulted in the slight increase of colour yellowness (statistically not confirmed at $p<0.05$) (Table 5). Reduction of redness with a slight increase of yellowness caused that Chroma of control and experimental blocks was not significantly different (Table 6). None of the examined starch preparations did not have adverse effect on the colour of meat products.

Table 5. Colour yellowness (b*) of meat blocks with the addition of modified starches during exposure

Sample	Exposure time (h)				
	0	0,5	1	2	3
Control	$14,21^{aA}$	$16,20^{aB}$	$16,58^{aB}$	$18,12^{abC}$	$18,56^{aC}$
Adamyl	$14,78^{aA}$	$16,86^{aB}$	$17,06^{abB}$	$17,42^{aB}$	$18,65^{aC}$
Skronet	$14,12^{aA}$	$16,43^{aB}$	$16,75^{aB}$	$17,99^{abC}$	$19,06^{aC}$
Adanet	$15,06^{aA}$	$16,98^{aB}$	$17,86^{bBC}$	$18,59^{bC}$	$18,38^{aC}$
Fremix	$14,52^{aA}$	$16,68^{aB}$	$17,38^{abBC}$	$17,85^{abCD}$	$18,81^{aD}$

$^{a, b}$ – means in a column with the same superscript letter are not different ($p<0.05$).

$^{A, B, C, \dots}$ – means in a row with the same superscript letter are not different ($p<0.05$).

Colour stability during storage is one of the quality features that are critical for consumers at the time of purchase. Therefore, the cross-sections of experimental products were exposed to the light. As the result were observed changes of colour parameters, which were also characteristic for the control meat products, such as: decrease of lightness and redness and increase yellowness. These changes are referred to graying and browning of corss-section of meat products. Experimental products containing starches were characterized by a similar range of lightness decrease as a control products. This decrease was at the level of about 1-2 units, and the final L* value for each experimental products was generally higher when the initial value were higher (fresh cross-section). There was no effect of any starch preparations on the course of lightness changes (Table 3).

Redness of experimental blocks decreased significantly during the exposure. Redness of cross-section of products without the addition of starches, before exposure was a*=8.33 and with the addition of starches was significantly lower and ranged from 5.89 to 6.23 (Table 4). After the end of exposure a* value of control sample decreased by almost 5 units and in the case of products with the addition of starch by almost 3 units (Table 4). Meat products with the addition of starches were characterized by significantly lower decrease of redness

(slower graying) than the control samples. It is very beneficial, previously unknown effect of starch on such an important quality feature of meat products, which is colour stability. This suggests the occurrence of "protective" effect of starch on nitrosohemochrome formed during heat treatment of meat products by the prevention of its oxidation. The mechanism of this process may only be hypothetical and requires further studies on the effect of starch on isolated pigments from cured and subjected to heat treatment meat.

During the exposure was also observed significant increase of yellowness of experimental and control products. The initial values ranged from approximately 14 to 15 and the final ranged from 18 to 19 (Table 5). It has been observed that the meat products with the addition of starches had similar yellowness to control samples. There was no significant effect of any of the starch on increase of b* value during exposure of meat products (Table 5).

Table 6. Chroma (C*) of meat blocks with the addition of modified starches during exposure

Sample	Exposure time (h)				
	0	0,5	1	2	3
Control	$16,47^{aA}$	$17,73^{aB}$	$17,46^{aB}$	$18,70^{abC}$	$18,90^{aC}$
Adamyl	$16,01^{aA}$	$17,63^{aB}$	$17,57^{aB}$	$17,84^{aB}$	$19,01^{aC}$
Skronet	$15,30^{bA}$	$17,22^{aB}$	$17,45^{aB}$	$18,50^{abC}$	$19,38^{aD}$
Adanet	$16,30^{aA}$	$17,72^{aB}$	$18,44^{aBC}$	$19,04^{bC}$	$18,78^{aC}$
Fremix	$15,76^{abA}$	$17,40^{aB}$	$17,99^{aB}$	$18,26^{abBC}$	$19,17^{aC}$

$^{a, b}$ – means in a column with the same superscript letter are not different ($p<0.05$).

$^{A, B, C, \ldots}$ – means in a row with the same superscript letter are not different ($p<0.05$).

Examined meat products during exposure were characterized by an increase of Chroma (C*) by about 3-4 units, mainly due to the increase of yellowness (b*) (Table 5). Chroma of meat products with the addition of starches after 3 h of exposure was slightly higher or similar to the values found for the control sample (Table 6). The studies of colour stability of meat products with the addition of modified starches are not reflected in the literature. Dzieszuka et al., (2005) studying the effect of starch on the quality of the sausage batter and Fernandez et al., (1996) on the texture of low-fat meat emulsion with the addition of starch found close relationships and trends as in the present work.

4. CONCLUSION

The use of modified starches as a functional additive to meat products resulted in a significant reduction of cooking loss during heat treatment. A particularly advantageous effect was occurred for skronet due to the characteristics of the gruel formed by heating of the suspension of this preparation and also in the some extent due to the higher pH value. The larger extent of hydration affected the texture characteristics of experimental products. Texture of experimental blocks was characterized by a lower hardness, cohesiveness, gumminess and chewiness.

It was found that the addition of all modified starches to the experimental products increased colour lightness, slightly increased yellowness and decreased redness of corss-section of these products (Table 3, 4, 5). These changes are closely associated with the degree of hydration of meat products due to the impact of starches addition.

Analysis of the colour of meat products with the addition of starches showed that they were characterized by a lower decrease of redness (slower graying) than the control samples during exposure. It is very beneficial, previously unknown effect of starch on such an important quality feature of meat products which is colour stability. This suggests the occurrence of "protective" effect of starch on nitrosohemochrome formed during heat treatment of meat products.

Due to their characteristics, examined preparations of modified starches can be valuable functional additive for meat products, which form the stability of proteins-fat-water systems, texture and colour parameters and improve production economics.

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