ACTA ICHTHYOLOGICA ET PISCATORIA
Vol. XXIV, Fasc. 2 Szczecin 1994

Ludmiła *STODOLNIK*, Bogusław *ZARZYCKI*, Stefan *IWASZKIEWICZ*, Jolanta *ŚWINIARSKA*

Fish technology

APPLICATION XANTHAN GUM TO STABILISE FROZEN-STORED MINCED COD MUSCLE

ZASTOSOWANIE KSANTANU DO STABILIZOWANIA ROZDROBNIONEJ TKANKI MIĘŚNIOWEJ DORSZY PRZECHOWYWANEJ W ZAMRAŻALNICZYCH WARUNKACH

Department of Fish Preservation, Agricultural University of Szczecin, Poland

Xanthan gum concentration of 0.2 and 0.4% and combination of both concentrations with 0.02% citric acid were used to treat minced cod muscles. Effects of the treatments on physical and chemical properties of the minces during storage at -25°C were followed.

INTRODUCTION

Following frozen storage, minced muscle tissue of lean fish shows a greatly reduced retention of tissue fluids and increased hardness, which decreases the technological utility of the tissue. Treatment with hydrocolloids can considerably diminish the effects mentioned (Da Ponte et al. 1985; Maslova and Novikova 1987). The texture enhancement and water retention increase caused by the treatment occur primarily due to increased viscosity (brought about by, e.g., carboxymethylcellulose, alginates, and xanthan gum) and as a result of gelation and hydratation (induced by, e.g., carrageenan, mixture of xanthan gum with certain hydrocolloids) (Da Ponte et al. 1985; Lanier 1986). On the other hand, various hydrocolloids differ in their ability to form bonds with proteins, lipids, salts, and other tissue components. The degree of such interaction and the resultant physical properties of the muscle tissue depend on molecular weight of a hydrocolloid, its concentration, type and availability of functional group in the polysaccharide (Kokini and Plutchok 1987; Yilmazer et al. 1991). Taking into account those properties of hydrocolloids which could after functional characteristics of fish meat applicability of xanthan gum, a bacterial polysaccharide obtained via biosynthesis (manufacturer: Food Concentrate Industry Central Laboratory in Poznań), to stabilise frozen-stored minced muscle tissue of the Baltic cod was tested.

MATERIALS AND METHODS

The pre-spawning Baltic cod individuals caught in March were used. The fish were filleted, skinned, and minced in an electric grinder provided with 3 mm hole diameter strainer. The mince thus obtained served to prepare 1-kg batches treated with 0.2 and 0.4% xantan gum and with 0.2%+0.02% and 0.4%+0.02% (w/w) xanthan gum + citric acid mixture. To ensure a uniform distribution of the additives in the minces, the batches were mixed for 2 min. in an electric kitchen appliance. The control consisted of an untreated mince sample. The batches were divided into 150 g 1 cm thick portions, each being subsequently wrapped into polythene film, frozen, and kept at -25°C. Prior to assays, the minces were thawed for about 17 h in air at 4°C.

Xanthan gum description (supplied by the manufacturer): the polysaccharide consists of D-glucose, D-mannose, and D-glucuronic acid at the molar ratio of 2.8 : 3 : 2. Water soluble; when dissolved in water, forms viscous high temperature-resistant solutions; extremely pseudoplastic properties in aquaeous solutions, able to permanently remain in a liquid medium as „suspended" fine particles; able to stabilise oil and fat emulsion in water; soluble and stable in alkaline and acidic media; stable at high salt concentrations.

Physical properties of the minces were assessed using the following assays:

- forced drip, as determined by measuring the surface area of drip produced by a 1 g sample placed for 10 min. under an 800 g load; expressed as drip coefficient in cm^2/g;
- hardness, as determined by measuring the surface area of a 1 g sample compressed for 10 min. by an 800 g load; expressed as compression coefficient in cm^2/g;
- thermal drip: 5 g mince samples were placed in polythene bags and heated in 80°C water for 20 min; expressed in per cent.

Structural changes in proteins were determined by assessing protein solubility at 0°C in 5% NaCl solution of pH 7.0 (1 : 8 tissue to solution ratio; 30 min. swelling time;15 min. extraction; 15 min. centrifugation at 4000 rpm). Extract absorbance was measured at 280 nm, the protein content being read from a standard curve prepared for the cod muscle tissue. The formaldehyde content was determined using the Castello and Smith (1973) technique. Muscle tissue pH was measured with an LBS-65 pH-meter. Results of all assays are given as arithmetic means of 3 measurements. The statistical treatment involved testing for significance of differences by means of the Student's t test and correlation coefficient (Czermiński et al. 1974).

RESULTS AND DISCUSSION

The data obtained are summarised in Figs 1 - 6 and in Table 1. The hydrocolloid-free minced cod muscle showed the amount of forced drip to increase with time of frozen storage (Fig. 1). Addition of both xanthan gum alone and its mixture with citric acid resulted in

tissue fluid retention over the 4 months of frozen storage being maintained at a level similar to the initial one (Fig. 1).

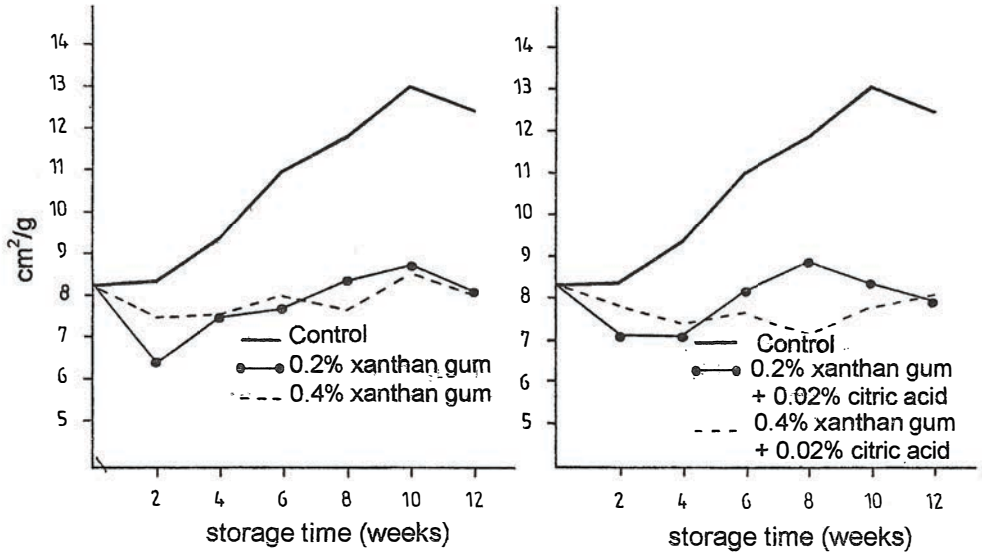

Fig. 1. Changes in cod muscle forced drip during frozen storage

The two xanthan gum concentrations used (0.2 and 0.4%) produced similar effects on forced drip inhibition during frozen storage (Fig. 1, Tab. 1). Addition of 0.02% citric acid to 0.2% xanthan gum did not affect the hydrocolloid's ability to bind tissue fluids, the ability being enhanced by addition of citric acid to 0.4% xanthan gum, compared with data for 0.4% xanthan gum alone (Fig. 1, Tab. 1). However, differences in water retention between minces containing 0.4% xanthan + 0.02% citric acid and 0.4% xanthan gum were non-significant (Tab. 1). The clear reduction of drip, brought about by the xanthan gum treatment indicates that the hydrophilic groups in the hydrocolloid under study are readily available and reactive in the raw material used. As demonstrated by Lim et al. (1984) xanthan gum easily forms hydrogen bonds in aquaeous medium, hence its fast association. The reduced drip of tissue fluids from minces treated with 0.02% citric acid + 0.4% xanthan gum can be realted to citric acid's effects on enhancing the hydrocolloid ability to reduce the surface tension. As shown by Yilmazer et al. (1991) xanthan gum at concentrations of up to 0.2% reduced surface tension of aquaeous solutions of acidic pH.

Xanthan gum was found to reduce the muscle tissue thermal drip (Figs 2 and 3), the effect being statistically significant (Tab. 1). On the other hand, those minces containing xanthan gum + citric acid mixture did not differ significantly in the amount of their thermal

drip from the samples treated with xanthan gum alone, added in the same amount (Figs 2 and 3, Tab. 1). Over the 4 months of frozen storage of the minced cod muscle, thermal drip tended to diminish with time. The decrease proved significant in those samples containing 0.2% xanthan gum, 0.2% xanthan gum + 0.02% citric acid, and in the control (Figs 2 and 3, Tab. 2). Changes in thermal drip of the minces imply that storage at -25°C for 4 months, followed by heating at 80°C does not disrupt the bonds between xanthan gum hydrophillic gropus and water contained in tissue fluids of the minces. The would indicate a strong interaction between xanthan gum and proteins and a high resistance of the first to thermal destruction. Similar changes in thermal drip were observed by Da Ponte et al. (1985) who analysed frozen-stored minced muscles of the Atlantic cod treated with 0.5% xanthan gum.

Table 1

Significance of differences (Student's t test values) between mean values of cod muscle parameters during frozen storage

Treatment	Forced drip	Thermal drip	Compression coefficient	Formaldehyde	Protein solubility in 5% NaCl solution
Control vs. 0.2% xanthan gum	7.169***	4.608***	14.813***	5.715***	0.591
Control vs. 0.4% xanthan gum	4.879***	12.624***	26.356***	5.681***	0.210
0.2% xanthan gum vs. 0.4% xanthan gum	0.392	4.140**	10.666***	8.417***	1.581
0.2% xanthan gum vs. 0.2% xanthan gum + 0.02% citric acid	0.419	0.065	0.139	0.663	2.694**
0.4% xanthan gum vs. 0.4% xanthan gum + 0.02% citric acid	2.045	0.528	3.948**	0.515	1.772
0.2% xanthan gum + 0.02% citric acid vs. 0.4% xanthan gum + 0.02% citric acid	0.815	7.730***	8.738***	5.816***	0.822

** differences significant at p=0.05
*** differences significant at p=0.01

Table 2

Correlation coefficients between changes in cod muscle drip during frozen storage, resulting from treatments used

	Control	0.2% xanthan gum	0.4% xanthan gum	0.2% xanthan gum + 0.02% citric acid	0.4% xanthan gum + 0.02% citric acid
r	-0.722**	-0.836**	-0.117	-0.697**	-0.493

** correlation significant at p=0.05.

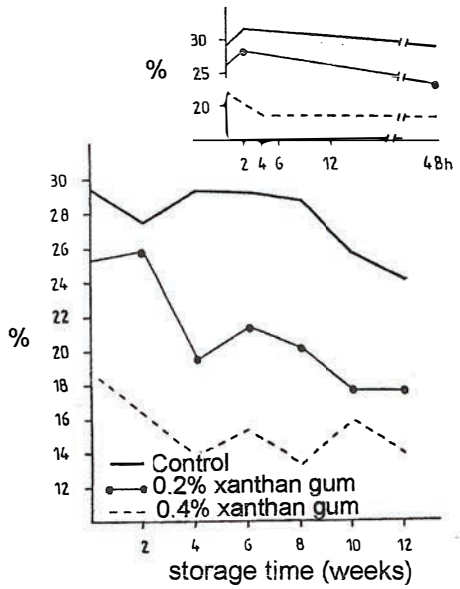

Fig. 2. Effects of xanthan gum treatment on changes in cod muscle thermal drip during frozen storage

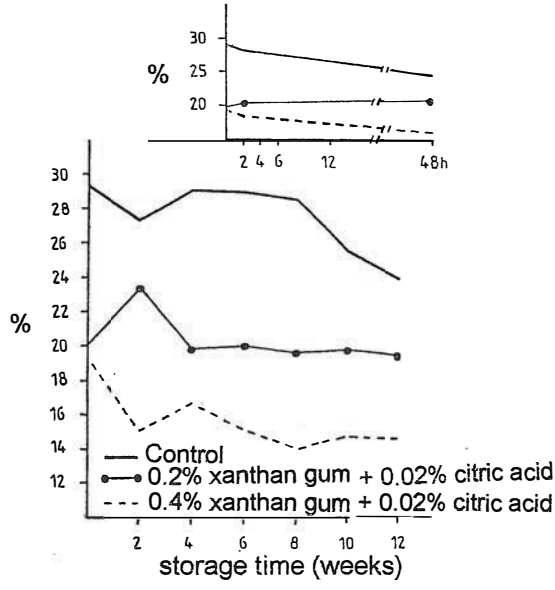

Fig. 3. Effectsof xanthan gum + citric acid treatment on changes in cod muscle thermal drip during frozen storage

The compression coefficient determined for the minced cod showed the xanthan gum treatment to increase the mince's susceptibility to permanent deformations (Fig. 4, Tab. 1). Those minces containing 0.2 and 0.4% xanthan gum became more compressed than the hydrocolloid-free samples. At the same time, changes produced in mince texture by 0.2 and 0.4% xanthan gum were non-significant (Tab. 1). The xanthan gum-induced loosening of cod muscle texture suggests that the hydrocolloid in question, when applied at 0.2 and 0.4% concentrations, does not increase mince viscosity the importance of which has been stressed by other workers (Da Ponte et al. 1985). As reported by Fox et al. (1983) xanthan gums in concentrations of up to 1% do not significantly increase viscosity, their solutions exhibiting pseudoplastic properties. Intensive elasticity reduction of muscle protein gels, produced by xanthan gum, was described in other studies (Foegeding and Ramsey 1987). Hibbert et al. (1987) found that it was at high xanthan gum concentrations only that visco-elastic structures emerged.

Addition of 0.02% citric acid with 0.2% xanthan gum produced no change in the mince treated in this way, compared to the sample enriched with 0.2% xanthan gum (Fig. 3, Tab. 1). On the other hand, the mince treated with 0.4% xanthan gum + 0.02% citric acid became softened more than that containing 0.4% xanthan gum alone (Tab. 1). Thus one may suspect that the combination of 0.4% xantan gum + 0.02% citric acid contributes to disaggregation of protein polypeptide chains and/or muscle fibres, thus inducing cod meat plasticity. Fox et al. (1983) found xanthan gum to stabilise texture of meat treated with acetic acid. Hennock

et al. (1984) reported that a strong interaction between proteins and xanthan gum, improving rheological characteristics of the product, may occur in the presence of acetic acid.

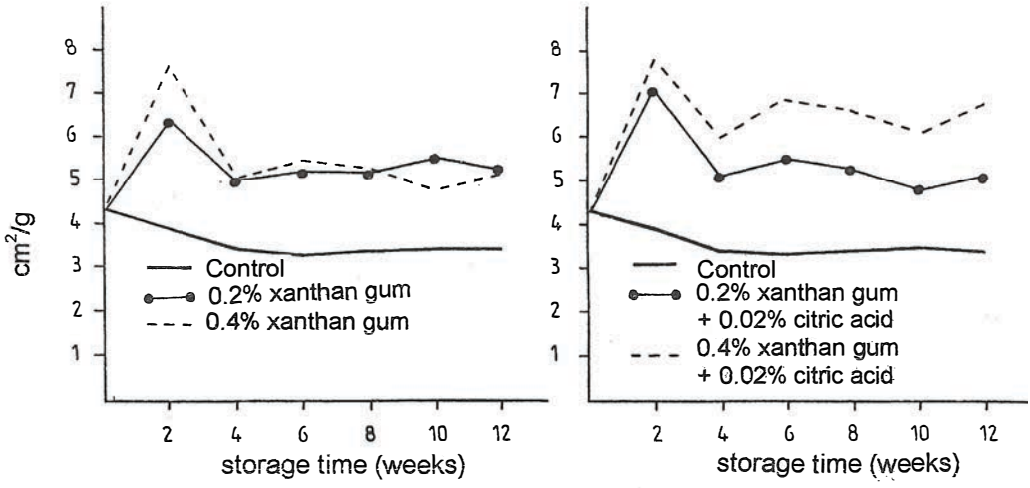

Fig. 4. Changes in compression coefficient of cod muscle during frozen storage

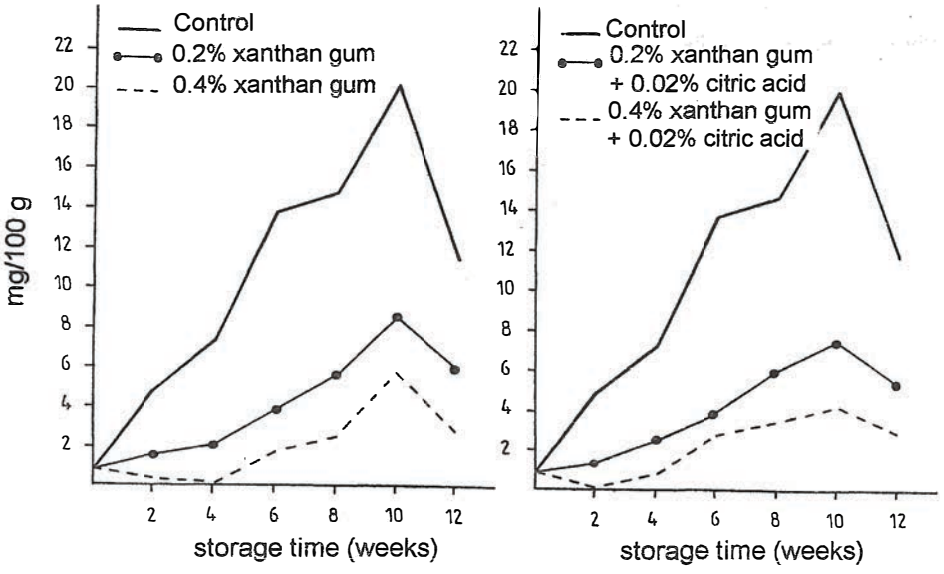

Fig. 5. Changes in cod muscle formaldehyde content during frozen storage

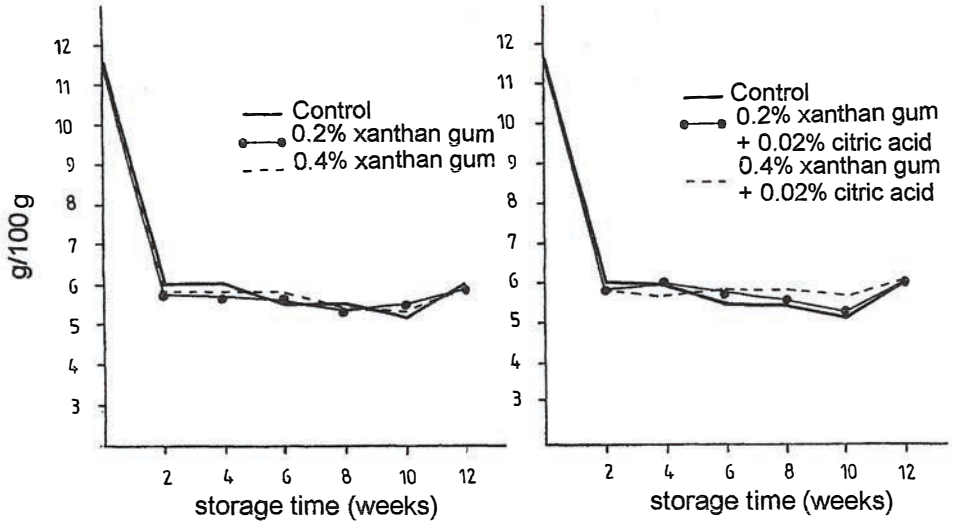

Fig. 6. Changes in cod muscle protein solubility in 5% NaCl solution during frozen storage

Dynamics of changes in the content of formaldehyde, a stong denaturation agent for cod muscle proteins, involved a rapid increase in the control and inhibitory effect of xanthan gum on formaldehyde release (Fig. 5). The higher xanthan gum concentration (0.4%) worked better in slowing down the formaldehyde release in the frozen-stored cod muscles than did the 0.2% hydrocolloid concentration (Fig. 5, Tab. 1). The presence of citric acid together with both concentrations of xanthan gum had no effect on changes in the tissue formaldehyde content, compared with the two xanthan gum treatments (Fig. 5, tab. 1). The mechanism whereby xanthan gum affect the cod muscle tissue formaldehyde content during frozen storage may involve demethylase immobilisation and/or a xanthan gum-formaldehyde interaction. Some hydrocolloids are known to reduce enzymatic activity (Synowiecki and Sikorski 1983). The significantly lower formaldehyde content, however, did not slow down the 5% NaCl protein solubility rate following frozen storage (Fig. 6). This would indicate that xanthan gum does not protect proteins from formaldehyde-induced structural changes, but - at the same time - one is led to suppose that xanthan gum is capable of interacting with cod proteins subject to denaturation. That ability is demonstrated by the high tissue fluid retention in xanthan gum-treated minces (Figs 1 and 2) and by the maintenance of delicate meat texture, in spite of similar protein solubility in xanthan gum-treated samples and in the control during frozen storage (Figs 4 - 6, Tab. 1). As shown by the relevant literature data (Synowiecki and Sikorski 1983), proteins affected by denaturation form more stable complexes with polysaccharides than native proteins, which the present study may also suggest with respect to proteins of xanthan gum-treated and frozen-stored cod muscle tissue.

The xanthan gum treatment applied was found to produce no change in cod muscle pH during frozen storage. The pH values ranged from 6.60 in the control and xanthan gum treated samples to 6.50 in those enriched with xanthan gum + citric acid. Consequently, pH changes played no important part in reducing protein solubility under conditions of frozen storage.

The results obtained allow to conclude that xanthan gum applied to minced cod muscle at concentration of 0.2% and, particularly, 0.4% significantly reduces losses of tissue fluid and helps to maintain the delicate texture of cod meat, both before and after frozen storage. Consequently, xanthan gum can be used as an efficient texture and water retention stabiliser in processing minced meat of lean fish.

ACKNOWLEDGEMENT

The authors wish to thank Professor Henryk Switek, Ph.D., Deputy Director for Research of the Food Concentrate Industry Central Laboratory in Poznań, for making xanthan gum available for this study.

REFERENCES

Castell C.H., B. Smith, 1973: Measurement of formaldehyde in fish muscle using TCA extraction and Nash reagent. J. Fish. Res. Bd. Can., 30, 1 : 91-97.

Czerniński J., A. Iwasiewicz, Z. Paszek, A. Sikorski, 1974: Metody statystyczne w doświadczalnictwie chemicznym. [Statistical methods in chemical experiments]. PWN, Warszawa : 70-189. (In Polish).

Da Ponte D.J.B., J.P. Roozen, W. Pilnik, 1985: Effect of different hydrocolloids on the stability of frozen stored minced fillets of whiting and cod. In: Storage lives of chilled and frozen fish and fish products. IIR, Aberdeen (UK) : 97-102.

Foegeding E.A., S.R. Ramsey, 1987: Rheological water-holding properties of gelled meat batters containing iota carrageenan, kappa carrageenan or xanthan gum. J. Food Sci., **52** : 549-552.

Fox J.B.jr, S.A. Ackerman, R.K. Jenkins, 1983: Effects of anionic gums on the texture of pickled frankfurters. J. Food Sci., **48** : 1031-1035.

Hennock M., R.R. Rahalkar, P. Richmond, 1984: Effect of xanthan gum upon the rheology and stability of oil water emulsions. J. Food Sci., **49**, 5 : 1271-1274.

Hibbert D.J., A.M. Howe, A.R. Mackie, P.W. Purdy, M.M. Robins, 1987: Measurements of creaming profiles in oil-in-water emulsions. In: Food Emulsions and Foams [E. Dickenson, ed.]. The Royal Society of Chemistry, London.

Kokini J.L., G.J. Plutchock, 1987: Predicting steady and oscillatory shear rheological properties of CMC/guar blends using the Bird-Carredu constitutive model. J. Texture Studies, **18** : 1-3.

Lanier T.C., 1986: Functional properties of surimi. Food Technol., **40**, 3 : 107-114.

Lim T.U., J.T. Uhl, R.K. Prud'Homme, 1984: Rheology of self-associating concentrated xanthan solution. J. Rheology, **26** : 367-370.

Maslova G.V., M.I. Novikova, 1987: In improvement of minced fish products quality in cold storage. XVIIth Intern. Congress of Refrigeration. Vien 1987. Proceedings vol. C, Biology and Food Science : 682-688.

Synowiecki J., Z.E. Sikorski, 1983: Chemiczne reakcje białek żywności. IV. Reakcje z polisacharydami. [Chemical reactions of food protein. IV. Reactions with polysaccharides]. Przem. Spoż., **8** : 357-360. (In Polish).

Yilimazer G., A.R. Carrillo, J.L. Kokini, 1991: Effect of propylene glycol alginate and xanthan gum on stability of O/W emulsions. J. Food Sci., **56**, 2 : 513-517.

Translated by: Dr T. Radziejewska

Ludmiła *STODOLNIK*, Bogusław *ZARZYCKI*, Stefan *IWASZKIEWICZ*, Jolanta *ŚWINIARSKA*

ZASTOSOWANIE KSANTANU DO STABILIZOWANIA ROZDROBNIONEJ TKANKI MIĘŚNIOWEJ DORSZY PRZECHOWYWANEJ W ZAMRAŻALNICZYCH WARUNKACH

STRESZCZENIE

Analizowano wpływ dodatku ksantanu w stężeniach 0,2 i 0,4% oraz jego mieszaniny z 0,02% kwasu cytrynowego do rozdrobnionej tkanki mięśniowej dorszy na jej właściwości fizykochemiczne w czasie przechowywania w temperaturze -25°C. Ksantan w zastosowanych stężeniach obniża istotnie wyciek soków tkankowych, także w obecności kwasu cytrynowego i przy zmienionej strukturze białek pod wpływem zamrażalniczego przechowywania i rozmrażania oraz obróbki cieplnej. Tworzy delikatną konsystencję farszu. Zwalnia szybkość nagromadzania się aldehydu mrówkowego proporcjonalnie do stężenia ksantanu w mięsie dorsza w czasie zamrażalniczego składowania.

Received: 1994.03.18

Author`s address:

Prof. Tit. D.Sc. Ludmiła Stodolnik
Department of Fish Preservation
Agricultural University of Szczecin
Kazimierza Królewicza 4, 71-550 Szczecin Poland