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# EFFECT OF SOME ADDITIVES ON THE WATER BINDING ABILITY AND CONSISTENCY OF THE MODEL PRODUCT CONTAINING PSE MEAT

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Summary. The effect of the addition of functional proteins: soy and milk proteins and of transglutaminase enzyme on the improvement of water binding ability of the meat tissue, binding of the bloc of the processed meat and the texture profile of the model product, with the significant participation of PSE meat, was examined. Based on the conducted studies, it was found that the addition of functional proteins increased water binding ability of the normal and PSE meat and by this, decreased the thermal loss and deteriorated tearing strength of the product. The addition of transglutaminase to the product, manufactured from PSE meat caused stronger binding of the bloc and strengthened the texture but decreased the water binding ability of the muscle tissue. Only combined application of functional proteins and transglutaminase improved the water binding ability as well as consistency of the model product, manufactured from PSE meat. The water binding ability of the muscle tissue affected significantly the size of the thermal drip, binding ability of the bloc and texture properties of the model product.

Keywords: PSE meat, microbial transglutaminase, water binding ability, consistency, protein additives, texture profile analysis (TPA).

## INTRODUCTION

Pork with watery structure, being specified as PSE (pale, soft, exudative) meat is one of the most frequently occurring quality deviations. The PSE meat differs from the normal one in brighter and less stable colour, soft consistency, incoherent and non-elastic structure and a considerable wateriness that results from a lower water holding capacity; in consequence, this water may exude from the meat.

The mechanism of formation of PSE meat consists in disturbances in post-slaughter metabolism: sudden run of glycogenolysis process and quick accumulation of lactic acid in muscles. In consequence of these changes, occurring at a high temperature of meat, i.e. 38 - 40°C, the far-advanced denaturation of sarcoplasmic proteins takes place and they are precipitated on fibres of actomyosin. It leads to blocking of a certain quantity of groups of polar protein molecules, decreasing by this the quantity of water bound with these molecules and this water exudes from muscular tissue. If denaturation took place in a big part of the muscle, the changes appear also in the structure of tissue, which loses its elasticity and coherence [3,6].

The PSE meat is characterized by a lowered utility and processing value. The quality of products, manufactured from this meat is worse due to the lack of the appropriate consistency, expressed by deterioration of texture properties, weak binding ability of the bloc and excessive quantity of thermal loss.

The unfavorable consequences, resulting from processing of PSE meat may be partially moderated by the application of substances that bind firmly water such as e.g. functional proteins. During the recent years, a high interest has been concentrated on transglutaminase as functional additive [1,2,4,5]. Transglutaminase (TG) is an enzyme that catalyses the polymerization and crosslinking of protein through the formation of covalent bonds between protein and peptide molecules. It is causing far-advanced modifications in their structure what may have an effect on the change in water binding ability by the muscle tissue and on the improvement of texture of the final product.

The aim of the conducted studies was to determine the effect of the addition of some functional proteins: soy protein and milk protein, and of transglutaminase on water binding ability, binding of meat bloc and texture profile of the model product with the considerable participation of PSE meat.

## MATERIALS AND METHODS

The research material for the studies consisted of finely ground canned meat product containing 50% of normal or PSE pork of class I, 25% of pork, class III obtained from foreshrank and 25% of dewlap. The pork of class I consisted of *m. Semimembranosus* and *m. Biceps femoris*, being selected according to the following criteria:

- normal meat – RFN, characterized by value $pH_2$ 5.9 - 6.3 after 24 h from slaughter and electric conductivity below 10 milisimens (mS);

- watery meat – PSE – characterized by value $pH_2$ below 5.8 after 24 h from slaughter and conductivity above 10 mS.

The raw meat materials were disintegrated in grinder, supplied with a plate diameter 3 mm and then, chopped in the cutter for 10 minutes at the temperature below 12°C. During chopping, the technological water in a form of ice was added in the following quantities: 20, 30, 40 and 50% in relation to the weight of raw meat materials. Also, sodium ascorbate – 0.05% and sodium glutamate – 0.11% in relation to the weight of raw meat materials and curing mixture (99.4% NaCl and 0.6% $NaNO_2$) in the quantity of 2% in relation to the weight of final product, were added. Besides it, during the chopping, the following additives were added to the selected variants of the preparation: microbiological transglutaminase "Activa WM" (0.3% as calculated into the weight of the batter) and instead of 10% of raw meat materials, the equivalent quantity of the following protein preparations (hydrated in ratio 1:4): soy protein "Supro Ex-33", or sodium caseinate "Amipur". The batter was packed in 450 g cylinder cans, closed and pasteurized at temperature of 75°C till reaching the temperature of 72°C in the center of the meat bloc. Then, the cans were cooled down to a room temperature and stored in the refrigeration room at temperature of 2 - 4°C till commencing the studies.

The experiment included 4 levels of water addition to the batter: 20%, 30%, 40% and 50%. For each level of water, the samples of RFN and PSE meat were used (codes of the particular variants were "N" and P", respectively), without protein additive and with soy protein (S) or caseinate (C), (codes "C/N" or "S/N" and "C/P" or "S/P", respectively). Also, the samples of PSE meat with the addition of protein and without it, containing 0.3% additive of transglutaminase (codes "C/P/II" or "S/P/II" and "C/P/I" or "S/P/I" respectively). In each experimental variant, 3 cans were examined.

The following analytical and measuring methods were employed:

- water content was determined by dryer method according to PN-ISO 1442:2000;
- protein content was determined by the Kjeldahl method according to PN-75/A-04018;
- thermal loss level was determined by the weighting method according to own methodology [6];
- slice strength was measured by UTM Zwick apparatus model 1445 MOPS according to own methodology [8];
- the profile analysis of texture (fracturability-force, fracturability-deformation, hardness, cohesiveness, gumminess, springiness and chewiness) was

performed by instrumental method, using UTM Zwick model 1445 MOPS (parameters of the test were: deformation – 80%, speed of traverse – 60 mm $min^{-1}$, thickness of the sample – 20 mm and diameter – 25,4 mm).

The statistical evaluation of the results was performed, using Statgraphics for Windows ver. 3.1.

## RESULTS AND DISCUSSION

The experimental results are presented in the mean values in Tables 1-3 and the results of multifactor analysis ANOVA are given in Table 4. These data indicate that the model products, containing PSE meat were characterized by lower water content, higher protein content, higher thermal loss and lower slice strength of slices as compared to the products, produced from the normal meat. These differences were statistically significant (see Tab. 4). Besides it, the PSE samples had a significantly lower fracturability and springiness, higher hardness in comparison to the samples from the normal meat and similar cohesiveness, chewiness and gumminess as the normal meat samples. The addition of functional proteins alone increased significantly the water content and decreased the thermal loss. At the same time, the slice strength of the product was weakened what was particularly demonstrated in case of the products, manufactured from normal meat. The addition of functional proteins modified the studied texture properties of RFN and PSE meat samples only to a small degree.

The addition of transglutaminase preparation to the PSE meat samples improved significantly the slice strength of the product but it increased the thermal loss and the product was characterized by lower water content in comparison to the RFN meat. Simultaneously, TG addition caused at least a significant improvement of texture. It was demonstrated in the significant increase of the values of the studied texture parameters. These results show that the addition of transglutaminase caused the improvement of binding of the consistency of the product's bloc and strengthening of its texture. At the same time, the water binding ability of the product was significantly lowered. It results from the way of the enzyme's action, which participates in formation of strong covalent crosslinking between the molecules of proteins and peptides and caused such strengthening of protein structures that the additional mechanical water exuding from the PSE meat product took place. Only in consequence of combined application of functional proteins and transglutaminase, the model product was obtained from PSE meat that was capable of water binding ability on a similar level as in the case of RFN meat product; it was characterized by a similar thermal loss but had a better consistency. It was confirmed by the higher slice strength of the product and higher values of parameters of texture profile analysis (TPA), related to the samples of variants "P/II" as compared to "P" samples.

A type of protein as well as the quantity of water added to the batter had a statistically significant effect on all the examined quality properties of the products. The samples with sodium caseinate had higher water and protein content, higher thermal loss but also, higher slice strength of the product as compared to the products with soy protein. Apart from it, they had higher values of all measured parameters of texture. Together with the increase of the water added to batter, the quantity of water in the product was increasing and the slices strength was decreasing, the texture of the product was deteriorated what was manifested by the linearly decreasing values of the studied properties of the texture. The addition of technological water to the batter, not exceeding 30 % did not cause the increased thermal loss.

The results of correlation calculations are given in Table 5. Values of the correlation coefficients show that between the studied variables, strong relationships existed. All the examined parameters of texture were mutually correlated, at least on the significance level $P<0.05$. The exception was the relation between fracturability-deformation and cohesiveness where the relationship was not found. The slice strength was very highly significantly correlated with all texture parameters and with protein content whereas it was negatively correlated with the water content. The increase of the thermal loss was related to the increase of water content in the product ($P\leq0.001$) and the decrease of protein content ($P\leq0.01$), besides, it had an influence on the rise of values of two texture properties: fracturability – deformation ($P\leq0.001$) and fracturability-force ($P\leq0.05$). Protein content was statistically very highly significantly positively correlated with slice strength and values of all texture properties, except for fracturability-deformation. On the other hand, it was negatively correlated with the thermal loss ($P\leq0.01$) and water content ($P\leq0.001$). Together with the increase of water content in the product, values of all the measured texture properties were very highly significantly decreasing, except for fracturability-force, the value of which was rising ($P\leq0.01$). Also, the slice strength was decreasing ($P\leq0.001$) while the quantity of thermal loss was increasing ($P\leq0.001$). From the above it results that water binding ability was significantly related to the thermal loss, binding of the bloc and texture properties of the product.

**Table 1.** Texture profile analysis of model products containing sodium caseinate

| Discriminants | Variants | Water addition [%] | | | |
|---|---|---|---|---|---|
| | | 50 | 40 | 30 | 20 |
| Hardness [N] | N | 80.87 | 94.98 | 107.99 | 121.73 |
| | C/N | 79.32 | 93.11 | 100.61 | 112.30 |
| | P | 81.08 | 99.99 | 104.82 | 119.04 |
| | C/P | 79.15 | 91.12 | 109.51 | 123.62 |
| | C/P/I | 114.73 | 129.40 | 136.79 | 149.03 |
| | C/P/II | 95.79 | 117.36 | 121.98 | 137.91 |
| Fracturability-force [N] | N | 46.48 | 56.70 | 60.22 | 68.21 |
| | C/N | 43.23 | 54.81 | 55.41 | 63.33 |
| | P | 44.17 | 51.12 | 58.72 | 65.89 |
| | C/P | 46.51 | 45.41 | 63.55 | 68.86 |
| | C/P/I | 73.06 | 86.25 | 100.80 | 114.44 |
| | C/P/II | 76.84 | 67.84 | 87.45 | 92.65 |
| Fracturability-deformation [%] | N | 49.50 | 53.29 | 50.05 | 51.50 |
| | C/N | 50.32 | 51.85 | 50.59 | 51.19 |
| | P | 51.07 | 50.42 | 51.67 | 51.65 |
| | C/P | 52.29 | 49.54 | 52.14 | 51.17 |
| | C/P/I | 54.15 | 54.96 | 54.84 | 55.34 |
| | C/P/II | 56.07 | 52.91 | 56.13 | 55.10 |
| Cohesiveness | N | 0.161 | 0.161 | 0.146 | 0.141 |
| | C/N | 0.153 | 0.153 | 0.152 | 0.152 |
| | P | 0.155 | 0.155 | 0.154 | 0.154 |
| | C/P | 0.149 | 0.149 | 0.152 | 0.150 |
| | C/P/I | 0.177 | 0.177 | 0.150 | 0.150 |
| | C/P/II | 0.168 | 0.168 | 0.150 | 0.150 |
| Gumminess [N] | N | 11.45 | 15.39 | 15.82 | 18.59 |
| | C/N | 12.27 | 14.26 | 15.35 | 17.04 |
| | P | 11.72 | 15.48 | 16.16 | 18.89 |
| | C/P | 11.83 | 13.62 | 16.68 | 18.89 |
| | C/P/I | 18.36 | 23.26 | 20.85 | 23.31 |
| | C/P/II | 14.48 | 19.79 | 18.91 | 22.16 |
| Springiness [mm] | N | 5.64 | 6.72 | 7.37 | 6.31 |
| | C/N | 5.38 | 6.14 | 6.56 | 7.21 |
| | P | 5.63 | 6.30 | 6.41 | 6.89 |
| | C/P | 5.83 | 5.66 | 7.22 | 7.63 |
| | C/P/I | 6.62 | 8.62 | 8.58 | 9.90 |
| | C/P/II | 6.93 | 8.60 | 8.99 | 10.23 |
| Chewiness [N mm] | N | 64.66 | 104.29 | 116.58 | 154.48 |
| | C/N | 65.89 | 88.47 | 101.82 | 122.86 |
| | P | 66.48 | 97.62 | 103.05 | 130.15 |
| | C/P | 68.97 | 76.68 | 119.08 | 144.13 |
| | C/P/I | 121.31 | 139.57 | 157.89 | 176.17 |
| | C/P/II | 99.41 | 171.89 | 169.97 | 226.70 |

Variants: N – normal meat; C – caseinate, S – soy protein, C/S/N normal meat with proteins; P – PSE meat; C/S/P – PSE meat with proteins; P/I – PSE meat with transglutaminase; P/II – PSE meat with transglutaminase and protein C or S.

**Table 2.** Texture profile analysis of model products containing soy protein

| Discriminants | Variants | Water addition [%] | | | |
|---|---|---|---|---|---|
| | | 50 | 40 | 30 | 20 |
| Hardness [N] | N | 66.56 | 90.37 | 93.81 | 118.96 |
| | S/N | 61.87 | 79.22 | 94.29 | 117.24 |
| | P | 73.73 | 91.29 | 97.91 | 110.55 |
| | S/P | 67.56 | 78.78 | 92.20 | 122.59 |
| | S/P/I | 102.77 | 120.19 | 117.26 | 139.81 |
| | S/P/II | 87.75 | 103.33 | 114.36 | 149.39 |
| Fracturability-force [N] | N | 43.64 | 50.44 | 54.86 | 58.57 |
| | S/N | 36.78 | 47.44 | 51.62 | 57.80 |
| | P | 39.54 | 46.24 | 50.49 | 48.16 |
| | S/P | 41.63 | 13.47 | 48.51 | 57.10 |
| | S/P/I | 72.43 | 71.69 | 74.67 | 81.64 |
| | S/P/II | 67.01 | 77.76 | 79.77 | 89.68 |
| Fracturability-deformation [%] | N | 53.14 | 53.33 | 50.38 | 47.40 |
| | S/N | 51.45 | 53.31 | 49.68 | 48.56 |
| | P | 47.91 | 48.30 | 48.14 | 45.93 |
| | S/P | 51.22 | 50.85 | 50.12 | 48.00 |
| | S/P/I | 52.73 | 51.81 | 51.57 | 49.57 |
| | S/P/II | 55.30 | 56.24 | 63.19 | 52.56 |
| Cohesiveness | N | 0.132 | 0.143 | 0.151 | 0.160 |
| | S/N | 0.133 | 0.149 | 0.146 | 0.170 |
| | P | 0.138 | 0.149 | 0.148 | 0.160 |
| | S/P | 0.137 | 0.150 | 0.150 | 0.150 |
| | S/P/I | 0.148 | 0.157 | 0.165 | 0.160 |
| | S/P/II | 0.146 | 0.156 | 0.149 | 0.170 |
| Gumminess [N] | N | 8.86 | 13.01 | 14.21 | 18.84 |
| | S/N | 8.23 | 11.77 | 13.78 | 19.78 |
| | P | 10.25 | 13.65 | 13.72 | 18.06 |
| | S/P | 9.21 | 11.86 | 13.88 | 17.96 |
| | S/P/I | 15.41 | 19.14 | 19.62 | 22.18 |
| | S/P/II | 12.95 | 16.35 | 17.39 | 25.72 |
| Springiness [mm] | N | 5.49 | 6.16 | 6.33 | 7.41 |
| | S/N | 4.86 | 5.77 | 5.80 | 6.94 |
| | P | 4.82 | 5.42 | 5.55 | 6.42 |
| | S/P | 5.29 | 5.67 | 6.35 | 6.57 |
| | S/P/I | 6.20 | 6.01 | 7.51 | 7.63 |
| | S/P/II | 6.28 | 7.44 | 7.24 | 8.62 |
| Chewiness [N mm] | N | 48.85 | 78.97 | 89.41 | 139.69 |
| | S/N | 40.64 | 68.11 | 79.55 | 137.66 |
| | P | 49.19 | 73.80 | 76.44 | 114.54 |
| | S/P | 49.10 | 66.70 | 87.83 | 118.62 |
| | S/P/I | 94.92 | 113.86 | 145.49 | 169.41 |
| | S/P/II | 81.39 | 122.66 | 126.46 | 218.87 |

Variants: N – normal meat; C – caseinate, S – soy protein, C/S/N normal meat with proteins;
P – PSE meat; C/S/P – PSE meat with proteins; P/I – PSE meat with transglutaminase;
P/II – PSE meat with transglutaminase and protein C or S.

**Table 3.** Mean results of tested discriminants (Codes of variants – see Table 1 and 2)

| Protein | Variants | Variants | Water addition [%] | | | |
|---|---|---|---|---|---|---|
| | | | 50 | 40 | 30 | 20 |
| Sodium caseinate | Water content [%] | N | 73.6 | 73.4 | 70.5 | 69.6 |
| | | C/N | 75.7 | 73.8 | 71.8 | 70.9 |
| | | P | 74.8 | 72.8 | 71.0 | 68.9 |
| | | C/P | 75.9 | 74.7 | 72.6 | 70.4 |
| | | C/P/I | 74.1 | 73.4 | 70.8 | 68.3 |
| | | C/P/II | 75.4 | 74.1 | 72.5 | 70.2 |
| | Protein content [%] | N | 12.0 | 12.4 | 13.3 | 14.2 |
| | | C/N | 12.5 | 12.4 | 13.4 | 14.5 |
| | | P | 11.8 | 12.8 | 13.2 | 14.3 |
| | | C/P | 12.0 | 12.8 | 13.6 | 14.4 |
| | | C/P/I | 12.8 | 12.7 | 13.2 | 14.6 |
| | | C/P/II | 12.4 | 12.8 | 13.8 | 14.5 |
| | Thermal loss [%] | N | 6.04 | 3.28 | 3.29 | 2.06 |
| | | C/N | 4.46 | 4.03 | 2.45 | 2.79 |
| | | P | 4.49 | 4.87 | 2.93 | 2.62 |
| | | C/P | 4.58 | 4.76 | 2.81 | 2.34 |
| | | C/P/I | 8.64 | 6.39 | 3.43 | 4.58 |
| | | C/P/II | 5.62 | 6.15 | 3.86 | 3.61 |
| | Slice strength [N/cm$^2$] | N | 2.69 | 3.09 | 3.21 | 3.98 |
| | | C/N | 2.56 | 2.97 | 3.03 | 3.28 |
| | | P | 2.16 | 2.87 | 3.38 | 3.42 |
| | | C/P | 2.15 | 2.40 | 3.03 | 3.06 |
| | | C/P/I | 3.74 | 4.21 | 4.78 | 4.91 |
| | | C/P/II | 3.57 | 4.06 | 4.38 | 4.71 |
| Soya | Water content [%] | N | 75.1 | 73.0 | 71.2 | 69.3 |
| | | S/N | 75.8 | 73.6 | 72.5 | 69.5 |
| | | P | 74.6 | 72.6 | 70.5 | 68.0 |
| | | S/P | 75.5 | 73.5 | 71.9 | 69.6 |
| | | S/P/I | 73.3 | 71.8 | 69.6 | 67.6 |
| | | S/P/II | 75.5 | 73.4 | 71.3 | 68.8 |
| | Protein content [%] | N | 10.0 | 11.6 | 12.1 | 14.4 |
| | | S/N | 9.6 | 11.0 | 10.1 | 13.8 |
| | | P | 10.2 | 12.7 | 13.2 | 14.8 |
| | | S/P | 10.2 | 11.4 | 11.2 | 13.5 |
| | | S/P/I | 11.3 | 12.8 | 12.9 | 15.0 |
| | | S/P/II | 10.4 | 11.2 | 12.0 | 12.8 |
| | Thermal loss [%] | N | 1.57 | 1.96 | 2.37 | 2.68 |
| | | S/N | 1.50 | 2.83 | 1.84 | 2.03 |
| | | P | 6.16 | 3.80 | 3.16 | 3.95 |
| | | S/P | 3.95 | 2.97 | 2.11 | 2.48 |
| | | S/P/I | 8.11 | 6.65 | 4.86 | 4.34 |
| | | S/P/II | 6.19 | 3.69 | 2.74 | 3.05 |
| | Slice strength [N/cm$^2$] | N | 2.37 | 2.78 | 2.91 | 3.50 |
| | | S/N | 1.94 | 2.47 | 2.88 | 3.30 |
| | | P | 2.05 | 2.58 | 3.10 | 3.23 |
| | | S/P | 2.02 | 2.47 | 2.94 | 3.06 |
| | | S/P/I | 3.51 | 3.54 | 4.34 | 4.64 |
| | | S/P/II | 2.97 | 3.57 | 4.17 | 4.37 |

**Table 4.** Results of multifactor ANOVA analysis

| Factor | | Water content [%] | Protein content [%] | Thermal Loss [%] | Slice strength [N/cm$^2$] | Fracturability [N] | Fracturability [%] | Hardness [N] | Cohesiveness | Gumminess [N] | Springiness [mm] | Chewiness [Nmm] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Protein | C | $72.5^{b}$ | $13.2^{b}$ | $4.17^{b}$ | $3.40^{b}$ | $67.05^{b}$ | $52.55^{b}$ | $108.56^{b}$ | $0.152^{b}$ | $16.84^{b}$ | $7.16^{b}$ | $121.90^{b}$ |
| | Sa | $72.0^{a}$ | $12.7^{a}$ | $3.54^{a}$ | $3.11^{a}$ | $57.81^{a}$ | $50.86^{a}$ | $99.03^{a}$ | $0.149^{a}$ | $14.99^{a}$ | $6.23^{a}$ | $96.67^{a}$ |
| | LSD | 0.16 | 0.10 | 0.30 | 0.10 | 1.81 | 0.46 | 1.48 | 0.002 | 0.37 | 0.14 | 4.41 |
| Water addition (%) | 50 | $75.0^{d}$ | $11.9^{a}$ | $5.11^{c}$ | $2.60^{a}$ | $52.30^{a}$ | $52.05^{bc}$ | $82.67^{a}$ | $0.144^{a}$ | $12.01^{a}$ | $5.55^{a}$ | $68.19^{a}$ |
| | 40 | $73.3^{c}$ | $12,3^{b}$ | $4.27^{b}$ | $3.08^{b}$ | $57.64^{b}$ | $52.37^{c}$ | $97.82^{b}$ | $0.153^{b}$ | $15.16^{b}$ | $6.52^{b}$ | $101.66^{b}$ |
| | 30 | $71.4^{b}$ | $13.3^{c}$ | $2.98^{a}$ | $3.54^{c}$ | $66.22^{c}$ | $51.45^{ab}$ | $108.32^{c}$ | $0.152^{b}$ | $16.60^{c}$ | $6.95^{c}$ | $116.04^{c}$ |
| | 20 | $69.3^{a}$ | $14.3^{d}$ | $3.04^{a}$ | $3.80^{d}$ | $73.57^{d}$ | $50.94^{a}$ | $126.37^{d}$ | $0.154^{b}$ | $19.89^{d}$ | $7.75^{d}$ | $151.23^{d}$ |
| | LSD | 0.22 | 0.14 | 0.43 | 0.14 | 2.55 | 0.66 | 2.10 | 0.003 | 0.53 | 0.20 | 6.24 |
| Variants | N | $72.0^{c}$ | $12.7^{a}$ | $2.90^{a}$ | $3.04^{b}$ | $56.42^{b}$ | $51.39^{c}$ | $96.90^{b}$ | $0.145^{a}$ | $14.29^{a}$ | $6.58^{c}$ | $96.88^{b}$ |
| | C/SN | $72.9^{e}$ | $12,8^{ab}$ | $2.75^{a}$ | $2.80^{a}$ | $51.58^{a}$ | $50.78^{bc}$ | $92.78^{a}$ | $0.150^{bc}$ | $14.06^{a}$ | $6.14^{ab}$ | $88.78^{a}$ |
| | P | $71.7^{b}$ | $12.9^{b}$ | $4.00^{b}$ | $2.85^{a}$ | $50.62^{a}$ | $49.36^{a}$ | $97.71^{b}$ | $0.149^{b}$ | $14.68^{a}$ | $5.93^{a}$ | $88.89^{a}$ |
| | C/S/P | $73.0^{e}$ | $12.9^{b}$ | $3.25^{a}$ | $2.69^{a}$ | $52.34^{a}$ | $50.43^{b}$ | $95.32^{b}$ | $0.149^{b}$ | $14.42^{a}$ | $6.26^{b}$ | $92.56^{ab}$ |
| | P/I | $71.1^{a}$ | $13.2^{c}$ | $5.85^{c}$ | $4.13^{c}$ | $83.47^{d}$ | $53.50^{d}$ | $125.28^{d}$ | $0.158^{d}$ | $20.09^{c}$ | $7.48^{c}$ | $144.86^{c}$ |
| | P/II | $72.7^{d}$ | $13.1^{c}$ | $4.37^{b}$ | $4.01^{c}$ | $80.16^{c}$ | $54.78^{e}$ | $114.72^{c}$ | $0.153^{c}$ | $17.96^{b}$ | $7.76^{d}$ | $143.74^{c}$ |
| | LSD | 0.27 | 0.17 | 0.53 | 0.17 | 3.13 | 0.80 | 2.57 | 0.004 | 0.65 | 0.24 | 7.64 |

Means in columns with different superscript are significantly different ($P \leq 0.05$)

Variants: N – normal meat; C – caseinate, S – soy protein, C/S/N normal meat with proteins; P – PSE meat; C/S/P – PSE meat with proteins; P/I – PSE meat with transglutaminase; P/II – PSE meat with transglutaminase and protein C or S.

**Table 5.** Correlations between variables

| Discri-minants | Fr-f | Fr-d | Ha | Co | Gu | Sp | Ch | SS | TL | W |
|---|---|---|---|---|---|---|---|---|---|---|
| Fr-d | 0.629 *** | - | | | | | | | | |
| Ha | 0.855*** | 0.248** | - | | | | | | | |
| Co | 0.438 *** | 0.107 $^{ns}$ | 0.611 *** | - | | | | | | |
| Gu | 0.832 *** | 0.256 ** | 0.984 *** | 0.722 *** | - | | | | | |
| Sp | 0.855 *** | 0.469 *** | 0.859 *** | 0.524 *** | 0.857 *** | - | | | | |
| Ch | 0.848 *** | 0.365 *** | 0.943 *** | 0.659 *** | 0.958 *** | 0.942 *** | - | | | |
| SS | 0.888*** | 0.455 *** | 0.866 *** | 0.489 *** | 0.852 *** | 0.831 *** | 0.861 *** | - | | |
| TL | 0.183 * | 0.290 *** | 0.035 $^{ns}$ | 0.175 * | 0.065 $^{ns}$ | - 0.028 $^{ns}$ | 0.024 $^{ns}$ | 0.103 $^{ns}$ | - | |
| W | -0.493*** | 0.225 ** | - 0.783 *** | - 0.359 *** | - 0.736 *** | - 0.575 *** | - 0.656 *** | - 0.602 *** | 0.315 *** | - |
| P | 0.5697 *** | -0.0821 $^{ns}$ | 0.8240 *** | 0.449 *** | 0.790 *** | 0.710 *** | 0.759 *** | 0.633 *** | - 0.252 ** | -0.845 *** |

$^{ns}$ - not significant P>0.05, * - significant at P≤0.05,** - highly statistically significant at P≤0.01,
*** - very highly statistically significant at P≤0.001
Fr-f – fracturability-force, Fr-d – fracturability-deformation, Ha – hardness, Co – cohesiveness, Gu – gumminess, Sp – springiness, Ch – chewiness, SS - slice strength, TL – thermal loss, W – water content, P – protein content.

**Table 6.** Coefficient of Eigen value (loadings) for two First Components PC1 and PC2

| Discriminants | PC1 | % | PC2 | % |
|---|---|---|---|---|
| Fracturability-force (Fr-f) | 0.33 | 10.6 * | - 0.24 | 9.8 |
| Fracturability-deformation (Fr-d) | 0.13 | 4.2 | - 0.59 | 24.0 * |
| Hardness (Ha) | 0.37 | 11.9 * | 0.05 | 2.0 |
| Cohesiveness (Co) | 0.24 | 7.7 * | - 0.03 | 1.2 |
| Gumminess (Gu) | 0.37 | 11.9 * | 0.03 | 1.2 |
| Springiness (Sp) | 0.35 | 11.3 * | - 0.08 | 3.3 |
| Chewiness (Ch) | 0.37 | 11.9 * | - 0.03 | 1.2 |
| Slice strength (SS) | 0.34 | 11.0 * | - 0.12 | 4.9 |
| Thermal loss (TL) | 0.01 | 0.3 | - 0.52 | 21.1 * |
| Water content (W) | - 0.28 | 9.0 | - 0.43 | 17.5 * |
| Protein content (P) | 0.31 | 10.0 * | 0.34 | 13.8 * |
| Σ/loadings | 3.10 = 100% | | 2.46 = 100% | |

* variables with loadings > 10,0% of the sum absolute loadings (Σ/loadings).

The application of Principal Component Analysis (PCA) allowed the presentation of the correlations from Table 4 in a graphical way on a "biplot" for the variables in multivariate space as shown on Fig. 1. From PCA analysis it results that the first principal component - PC 1 explained 64.3 % of total variation and the following variables were most important in their latent structure: fracturability – force, hardness, gumminess, springiness, chewiness and protein content. The second principal component - PC 2 explained further 17.0 % of total variation and its most important variables in latent structure were: fracturability-deformation, thermal loss, water content and protein content (see Tab. 6).

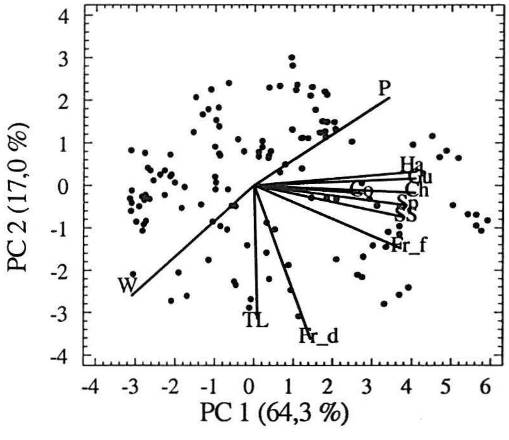


**Fig. 1.** Biplot for the variables in multivariate space.
*Fr-f* – fracturability-force, *Fr-d* – fracturability-deformation, *Ha* – hardness, *Co* – cohesiveness, *Gu* – gumminess, *Sp* – springiness, *Ch* – chewiness, *SS* - slice strength, *TL* – thermal loss, *W* – water content, *P* – protein content

## CONCLUSIONS

1. The addition of functional proteins increased water binding ability of RFN and PSE meat, decreased the thermal loss and deteriorated the slice strength of the product.
2. The addition of transglutaminase enzyme to PSE meat caused stronger binding of the bloc and strengthening of texture but it decreased water binding ability by the muscle tissue.
3. Combined application of functional proteins and transglutaminase improved water binding ability as well as consistency of the model product, manufactured from PSE meat.
4. Water binding ability of the muscle tissue affected significantly the quantity of thermal loss, binding ability of the bloc and texture properties of the model product.

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## WPŁYW WYBRANYCH DODATKÓW FUNKCJONALNYCH NA ZDOLNOŚĆ WIĄZANIA WODY I KONSYSTENCJĘ MODELOWEGO PRODUKTU ZAWIERAJĄCEGO MIĘSO PSE


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Streszczenie. Badano wpływ dodatku białek funkcjonalnych: białka soi i białka mleka oraz enzymu transglutaminazy na poprawę zdolności wiązania wody przez tkankę mięśniową, związanie bloku konserwy i profil tekstury produktu modelowego ze znaczącym udziałem mięsa PSE. Na podstawie przeprowadzonych badań stwierdzono, że dodatek białek funkcjonalnych zwiększył zdolność wiązania wody przez mięso normalne i PSE, zmniejszając tym samym wyciek termiczny, ale pogarszając wytrzymałość na zrywanie. Dodanie enzymu transglutaminazy do produktu z mięsa PSE spowodowało silniejsze związanie bloku i wzmocnienie tekstury, ale zmniejszyło zdolność wiązania wody przez tkankę mięśniową. Dopiero łączne zastosowanie białek funkcjonalnych i transglutaminazy poprawiło zarówno zdolność wiązania wody jak i konsystencję produktu modelowego z mięsa PSE. Zdolność wiązania wody przez tkankę mięśniową w istotnym stopniu wpływała na wielkość wycieku termicznego, związanie bloku i cechy tekstury produktu modelowego.



Słowa kluczowe: mięso PSE, mikrobiologiczna transglutaminaza, zdolność wiązania wody, konsystencja, białka funkcjonalne, profilowa analiza tekstury (TPA)