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EVALUATION OF FISH AND SQUID MEAT APPLICABILITY FOR SNACK FOOD MANUFACTURE BY INDIRECT EXTRUSION COOKING

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Abstract. Applicability of selected marine and freshwater fish and squid for snack food manufacture by indirect extrusion cooking was evaluated. Formulations consisting of various cereals and meat were extruded with a 20-DN single-screw laboratory extruder (Brabender, Germany). Meat of lean fish showed better extrusion characteristics than that of fat fish, fresh fish being superior in this respect to frozen fish. Washing of the fish meat was found to enhance meat utility in extrusion cooking. Myofibrilar proteins of cod proved most useful protein fraction to extrusion.

Key words: extrusion, fish, squid

INTRODUCTION

Extrusion, a modern technology of processing cereals, can be used for, i.a., manufacture of snack foods enriched with plant and/or animal protein. The literature contains reports on utilization of proteins contained in soy beans and other legumes (various peas and beans) as well as application of buckwheat and milk and its proteins (caseinates) to enrich the amino acid composition of extruded products. Extrusion of starch-containing materials mixed with animal muscle proteins is problematic because of a number of difficulties arising primarily from thermal instability of those formulations and from a basic thermodynamic difference between protein and starch molecules [Yurjew et al. 1989]. The high sensitivity of muscle proteins of slaughtered animals and fish to denaturation, coupled with a loss of numerous functional properties of protein during hot extrusion makes it necessary to explore other, less drastic, processing methods. As proposed by many authors, warm extrusion (at 70 to 130°C) seems to be one of them. Extrusion cooking at lower temperatures yields pellets which have an attractive, chip-like porous structure only after they have been dried and heated in a hot medium (oil, microwave oven). Addition of muscle protein usually reduces extrudate expansion, as

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observed, i.a., by Kołakowski et al. [1979, 1980] during direct and indirect extrusion of starch-krill formulae, and by Clayton [1992] and Maga and Reddy [1985] who applied indirect extrusion to rice flour-fish meal recipes. Those proteins form a kind of a film on the starch vector, thus inhibiting its expansion. The other reason could also be the high sensitivity of most protein fractions of meat of fish and other aquatic animals to thermal denaturation [Sikorski et al. 1994]. To reduce fish protein reactivity with starch during extrusion, Yamaguchi et al. [1988] suggested preliminary blending of fish meat with ethanol. On the other hand, the high utility of fish proteins as components enhancing the nutritive value of extruded foods remains unquestionable. Particularly useful in this context are regular or enriched fish minces, manufactured by mechanical separation, whereby skin and bones can be completely separated from meat [Kołakowski 1986]. Noguchi [1989] reported that Kushiro Fish Research Station in Hokkaido has successfully texturised sardine meat (*Sardinops melanosticta*). Sardine and defated soy flour were mixed in a 7:3 ratio, after adjustment of the water content to 50%, and then extruded with a twin-screw extruder (Kobe TCV-50L). Extrudates had a cooked texture like that of animal meat and different from that of other fish products. Choudhury et al. [1995] try to evaluate texturisation of pink salmon mince obtained from fillet trimmings using a twin-screw extruder (Clextral model BC-21). They concluded that the process has been successfully used to destroy undesirable enzymes and microorganisms and develop fibrous texture in the extrudate, and the process will find extensive application in restructuring or texturising food proteins to create protein gels, meat analogues, and consumer – ready microwaveable frozen product.

Choudhury et al. [1998] also investigated the effects of location and spacing of kneading elements on product attributes during twin-screw extrusion of pink salmon muscle and rice flour blends. They reported that specific mechanical energy, expansion ratio, and water solubility index decreased with increasing levels of fish solids. The results indicated that pink salmon muscle can be added to a starchy ingredient to increase protein content of expanded snack foods, without decreasing the desired product attributes, by manipulation of screw configuration with mixing element. The proportion of milk proteins in extrudates seems to be constrained by technological reasons as well, although those proteins are known for their relatively high resistance to thermal denaturation [Fornal et al. 1985, Śmietana et al. 1985, 1988]. Poznański et al. [1985] who extruded formulations consisting of buckwheat, barley, and corn flours with 25% addition of milk protein, found the reduction in expansion of melt, compared to that of flour, to be related to a lower content of insoluble starch-protein complex which plays a significant part in controlling the porous structure of extrudates. Other authors [Szpendowski et al. 1994] proposed to stabilize casein micelles with calcium ions to enhance the casein texturisation. The findings reported above allow to conclude that the addition of animal, particularly fish, protein to formulations intended for texturisation by extrusion is limited by technological constraints, but extremely desirable from the nutrition viewpoint.

The aim of this study was to apply of fish and squid meat for the production of third generation snacks by extrusion method.

MATERIALS AND METHODS

Materials

Starch sources. The basic components of the extrudates tested included starch-containing raw materials, henceforth termed starch sources, obtained from cereals and potatoes. The quality of the starch vectors used (listed below) met the requirements of the Polish standards: potato starch; Krupczatka-type wheat flour; corn grits; rice; potato puree.

Some of the starch vectors were prepared from cereals such that the composition of the ground fraction was identical with the original product. Grinding was performed in an HU-1 grain grinder (Feuma, the former GDR). The fraction, separated by sieving, of a particle size higher than that required by this study, was re-ground and thoroughly mixed with the already prepared fractions. The tests were run on starch sources of particle size ranging within 750-430 μm.

Fish protein sources. Fresh fish: Baltic cod (*Gadus morhua callarias* L.), Baltic herring (*Clupea harengus membras* L.), roach (*Rutilus rutilus* L.), and bream (*Abramis brama* L.) as well as frozen fish: hake (*Merluccius merluccius* L.), Atlantic mackerel (*Scomber scombrus* L.), and Baltic herring (*Clupea harengus membras* L.) were used directly or after washing with water like in surimi manufacture. The fish were headed and gutted; the carcasses were washed with water, passed through an NF 13DX separator (5 mm opening diameter size) to separate meat from bones and skin, and through a SUM 420 (Bibun, Tokyo) strainer (1 mm opening diameter). The final product consisted of finely ground meat without bones or skin was known as a MDM (Mechanically deboned meat). The meat tissue always made up 30% of the formulation by weight, the remaining part consisting in equal proportions (1:1:1:1) of starch vectors: potato starch, potato puree, wheat flour, and rice flour.

The meat was washed twice in tap water at 8°C for 10 min at the weight ratio of 1:3 and centrifuged in a vertical centrifuge (Bibun, Tokyo). The product obtained was tentatively termed “surimi”. In addition, MDM was obtained also from cod filleting wastes, the procedure used being identical to that applied to whole fish.

The squid (*Loligo loligo* L.) mantle meat was obtained by removing the skin, cleaning, and grinding in a 1 mm opening diameter grinder. The squid tentacle meat was obtained by separating the tentacles from the mouth cavity, grinding them in a 4 mm opening diameter grinder, and straining (1 mm opening diameter).

The proximate composition of the components and extruded blends is shown in Table 1.

Protein fractions. The fresh Baltic cod yielded three protein fractions obtained with Dyer’s procedure [Dyer et al. 1950]: sarcoplasmic, myofibrilar, and non-soluble proteins.

The sarcoplasmic proteins were mixed with NaCl such that the salt concentration obtained (4%) was identical to that in the remaining samples. Effects of individual protein fractions on expansion of potato starch-based melt were followed. The protein concentration used was 20%. The 2:1 compression screw was used at 50, 100, and 150 min^{-1} rotation speeds.

Table 1. Proximate composition of components and extruded blends, %
Tabela 1. Przybliżony skład surowców i ekstrudowanych mieszanin, %

Starch source Nośnik skrobiowy		Protein Białko	Fat Tłuszcz	Carbohydrate Sacharydy	Water Woda
Wheat flour ("Krupczatka") Mąka pszenna „Krupczatka"		12.2	2.1	74.3	10.9
Corn grits Kaszka kukurydziana		8.6	1.6	74.2	13.6
Rice Ryż		8.0	0.3	79.0	11.2
Potato puree Puree ziemniaczane		6.1	0.2	84.2	8.0
Potato starch Skrobia ziemniaczana		–	–	81.0	18.7
Fish – Ryby					
Hake – Morszczuk		16.3	3.1	–	79.0
	a	9.6	1.62	54.9	32.7
Bream – Leszcz		17.1	4.2	–	76.3
	a	9.8	1.95	54.9	31.9
Bream "Surimi" Surimi z leszcza		12.4	1.0	–	84.4
	a	8.41	0.99	54.9	34.3
Roach – Płoć		19.1	3.4	–	75.8
	a	10.42	1.71	54.9	31.7
Cod – Dorsz		16.8	0.3	–	81.6
	a	9.73	0.78	54.9	33.4
Fresh herring – Śledź świeży		15.4	8.2	–	74.4
	a	9.31	3.15	54.9	31.3
Frozen herring – Śledź mrożony		15.6	8.4	–	73.9
	a	9.4	3.21	54.9	31.1
Mackerel – Makrela		19.0	16.6	–	62.8
	a	10.4	5.67	54.9	27.8
Squid – Kalmar		17.9	1.3	–	79.1
	a	10.1	1.1	54.9	32.7
Squid tentacles Ramiona kalmara		17.5	2.0	–	78.5

a – blend consists of 30% fish meat + 70% starch vector ("Krupczatka" wheat flour + corn grits + potato puree + potato starch; 1:1:1:1).

a – mieszanina zawierająca 30% mięsa ryb + 70% nośnika skrobiowego (mąka pszenna „Krupczatka" + kaszka kukurydziana + puree ziemniaczane + skrobia ziemniaczana; 1:1:1:1).

Squid tentacle meat. The tests were carried out with squid tentacle meat the amount of which was varied, at 5% increments, from 20 to 40%. The meat was combined with two starch vectors. One was obtained by combining (1:1:1) pureed potatoes, rice flour, and the Wrocławska-type wheat flour. The other was a mixture (1:1.5:0.5:0.2) of the Krupczatka-type wheat flour, rice flour, potato starch, and pureed potatoes.

Thermal treatment of squid tentacles. Squid tentacles, separated from the mouth cavity, were cooked in boiling water for 1 or 2 minutes. Subsequently, they were ground in an 4 mm opening diameter grinder and passed through a secondary strainer (Bibun, Japan), equipped with a 1 mm mesh size sieve. The meat was combined with a starch vector consisting of equal parts of rice flour and the Krupczatka-type wheat flour. The meat contributed 30% to the melt weight.

Methods

Melt preparation. Starch vectors were blended for 3 min at 2890 min^{-1} with meat and/or water in an UMM10 processor (Stephan, Germany). Prior to extrusion, the formulations were conditioned for 1 h at room temperature to equalize moisture, following which they were fluffed by passing them through a 3 × 3 mm mesh size sieve.

Extrusion. The formulations were extruded on a 20 DN single-screw laboratory extruder (Brabender, Germany) equipped with:
- a Φ 19 grooved barrel (6 symmetrical 1 × 0.5 mm grooves) of 1/d = 20 ratio,
- three independent heating zones,
- a slit die (25 × 1 mm), screw of the compression ratio: 4:1; the screw rotational speed was adjustable within 0-250 min^{-1} (continuous adjustment),
- a PT 420A-10M-6 (Dynisco, USA) transducer covering the pressure range of 0 to 700 $kG \cdot cm^{-2}$,
- the temperature profile (from the inlet) was 75°, 98°, 98°C so the exit temperature of the melt was nearly 98°C.

During extrusion, the melt temperature, pressure, and torque were recorded by a Rikadenki (Japan) recorder.

Frying. The extrudates (pellets) were fried in hot oil (175°C) for 30 seconds, where they expanded to the final porous structure.

Determination of volume density and expansion index. The extrudate volume density was calculated from the volume to weight ratio. An extrudate sample of about 10 or 20 g was immersed in a water-containing graduated cylinder. The displacement volume corresponded to the sample volume. The expansion index (ε) was calculated as a ratio between volume densities of the extrudate after and before frying.

Texture. Texture parameters were measured on an Instron 1140 (England) device, using the Warner-Bratzler test (50 $mm \cdot min^{-1}$ knife speed; 0 to 500 N measuring cell). A force necessary to completely cut an extrudate sample with a single cut was recorded. The graphs obtained allowed to read sample hardness, T (the curve peak). The test device was interfaced to a computer and a printer, whereby a printout of the data obtained during each series of measurements (6 to 10 replicates) was produced.

Sensory evaluation. The six panellists described the overall appearance (colour, porosity, shape) and flavour of the extrudates before and after frying. The results are performed in concise form in Table 2. Perceptible fish flavour of the extrudates was non-acceptable by the panel.

Table 2. Extrudate appearance shape and flavour before and after frying
Tabela 2. Wygląd, kształt i zapach ekstrudatów przed i po smażeniu

Raw material Surowiec	Before frying Przed smażeniem	After frying Po smażeniu
Mackerel Makrela	coffee-and-milk coloration; structure: opaque, with matt surface, hard, streaks on non-gelatinised flour visible barwa kawowomleczna, struktura nieprzezroczysta o matowej powierzchni, twarda, widoczne białe smugi nieżżelowanej mąki	light-brown colour; irregular, shell-like shape; foaming weak, fairly uniform; perceptible fish flavour; few larger bubbles visible barwa jasnobrązowa, kształt nieregularny, muszelkowaty, słabe spienienie dość równomierne, wyczuwalny zapach i smak rybi, występują również pojedyncze większe pęcherze
Herring (fresh and frozen) Śledź (świeży i mrożony)	dirty grey coloration; opaque surface with milk-white streaks barwa szara (brudna), na powierzchni taśma nieprzezroczysta z białymi smugami (mleczne)	light-brown, non-uniform colour; foaming weak with few bubbles; perceptible fish flavour; irregular shape barwa jasnobrązowa, niejednorodna, spienienie słabe z pojedynczymi bąblami, wyczuwalny smak i zapach rybi, kształt nieregularny
Bream Leszcz	green-yellow coloration, slightly opaque with white dots of non-gelatinised flour; wrinkled surface barwa zielonożółta, słabo przezroczysta z białymi cętkami nieżżelowanej skrobi, powierzchnia pomarszczona	golden to golden-brown colour; irregular, undulated shape; foaming irregular, with few larger bubbles; perceptible fish flavour barwa złocista i złocistobrązowa, kształt nieregularny, pofalowany, spienienie nierównomierne z pojedynczymi większymi pęcherzami, smak i zapach rybi wyczuwalny
Cod Dorsz	straw-green coloration; surface wrinkled, glossy; cross-section shape resembling flattened three numeral barwa słomkowozielona, powierzchnia pomarszczona, błyszcząca, kształt na przekroju spłaszczonej trójki	light-golden colour; shape irregular, shell-like; foaming inhomogeneous, more intensive on the surface; fish flavour not perceptible barwa jasnozłocista, kształt nieregularny, muszelkowaty, spienienie niejednorodne, na powierzchni lepsze, niż wewnątrz „chrupek", smak i zapach rybi niewyczuwalne
Roach Płoć	straw-green coloration; surface wrinkled, slightly glossy; cross-section irregular in shape barwa słomkowozielona, powierzchnia pomarszczona, lekko błyszcząca, kształt na przekroju nieregularny	light-golden in colour; foaming inhomogeneous; larger bubbles on the surface, smaller and hard inside; fish flavour weakly perceptible barwa jasnozłocista, spienienie niejednorodne, na powierzchni pęcherze większe, wewnątrz mniejsze, twarde, słabo wyczuwalny posmak rybi
Hake Morszczuk	well-gelatinised structure, glossy, translucent; surface slightly wrinkled; flattened c-shaped scales struktura dobrze zżelowana, błyszcząca, przezroczysta, powierzchnia lekko pomarszczona, kształt łusek spłaszczonej litery c	golden colour; irregular, shell-like shape; no typically fish flavour; homogenous foaming barwa złocista, kształt nieregularny, muszelkowaty, brak smaku i zapachu typowego dla ryb, spienienie jednorodne
Squid Kalmar	straw-green colour; translucent, hard, crisp, well gelatinised structure barwa słomkowozielona, przezroczysta, struktura twarda, krucha, dobrze zżelowana	golden colour; irregular shape; inhomogeneous foaming: bubbles larger on the surface than inside; fish flavour weakly perceptible barwa jasnozłocista, kształt nieregularny, spienienie nierównomierne, na powierzchni pęcherze większe niż wewnątrz, słabo wyczuwalny smak i zapach rybi

RESULTS

Extrusion of starch vector-fish and squid meat formulations

Fish species effects. Applicability of "warm extrusion" to texturisation of starch-protein formulations containing fish and squid meat was tested (Fig. 1). The results obtained are summarized in Tables 2 and in Figures 2 and 3.

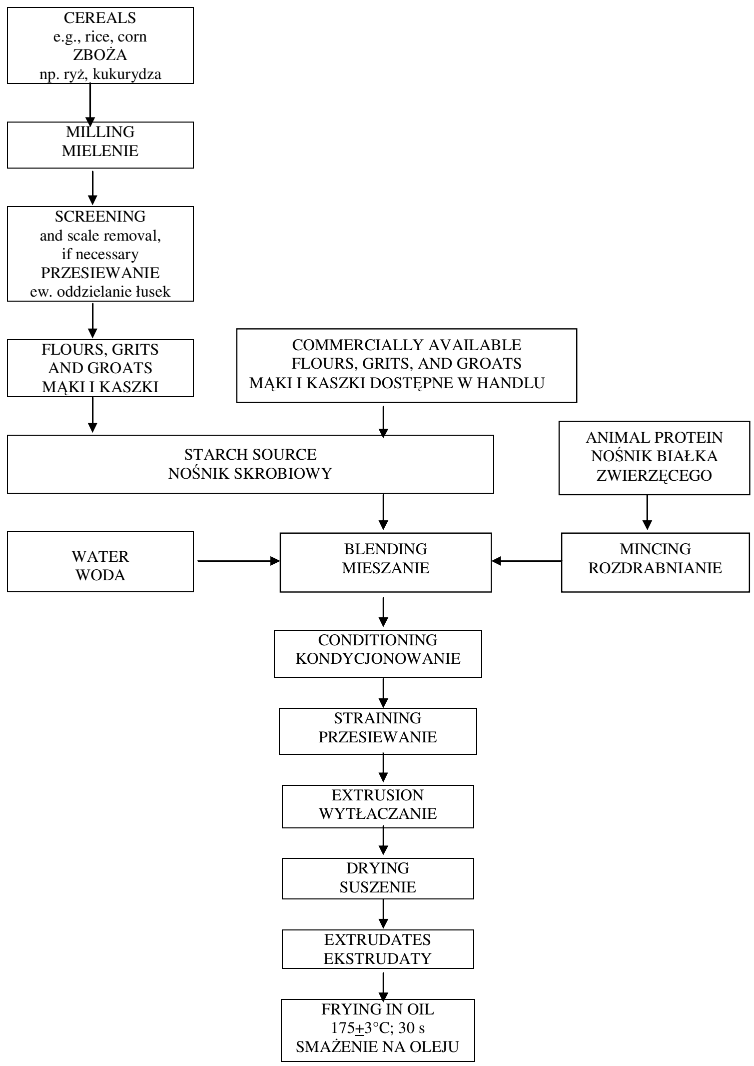

Fig. 1. Flow chart of experimental design
Rys. 1. Schemat badań

The highest expansion index (5.23) was recorded in the sample containing hake meat, while the lowest indices were produced by those samples containing mackerel (3.11) and frozen herring (3.22).

The expansion indices of the fresh herring meat-containing extrudates were found to be by 25% higher than those of the extrudates containing frozen herring. The extrudates manufactured with lean fish meat usually produced higher expansion indices than those containing fat fish meat.

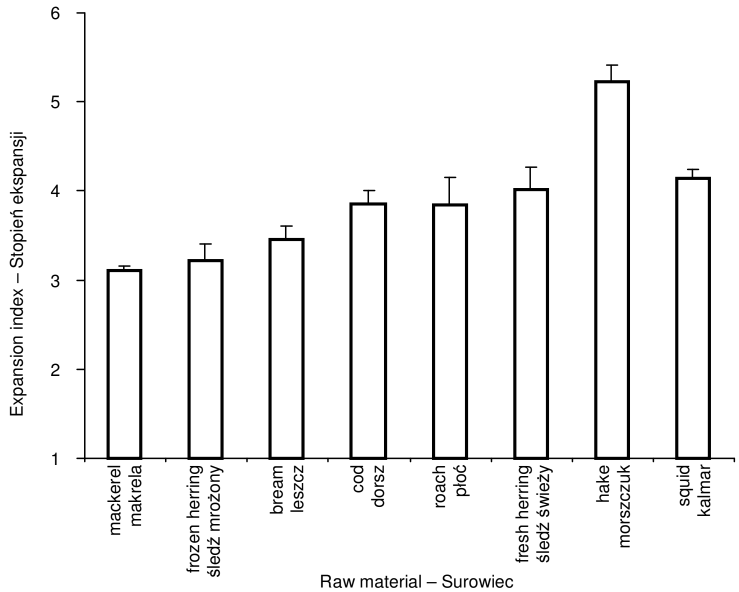

Fig. 2. Expansion indices of starch extrudates containing meat of various fish species and squid (starch vector: potato meat + potato puree + Krupczatka-type wheat flour + rice flour; 1:1:1:1)
Rys. 2. Porównanie stopnia ekspansji ekstrudatów skrobiowych z udziałem mięsa poszczególnych gatunków ryb i kalmara (nośnik skrobiowy: mączka ziemniaczana + puree ziemniaczane + mąka pszenna „Krupczatka" + mąka ryżowa; 1:1:1:1)

Meat of the fat fish (herring, mackerel) proved difficult to texturize; uniform and continuous extrusion could not be achieved. The extrudate leaving the die showed well-gelatinised sections (about 20 cm long), followed by sections with white smudges gradually blending with those having uniformly foamed structure. That was a result of the primary expansion: the melt was momentarily stopped, overheated, and expanded when leaving the die (Table 2).

The expansion indices of those extrudates containing squid meat were lower only than those produced by the hake meat-supplemented samples. However, certain exceptions from that rule occurred: lower fat contents were accompanied by higher expansion indices. For instance, the roach meat-containing extrudates showed expansion similar to that obtained in cod meat-containing samples. The hake meat, having fat content higher than that of cod, produced expansion indices higher by about 36%. The data show also that the expansion index depended not only on the meat fat content, but also by functional properties of proteins. It cannot be ruled out that the high expansion of the hake meat-containing extrudates was related to their high aldehyde contents. Merlucid meat is known to be very susceptible to protein cross-linking during frozen storage. In addition, extrusion of melt containing lean fish and squid meat proceeded uniformly at stable torque and pressure (Fig. 3).

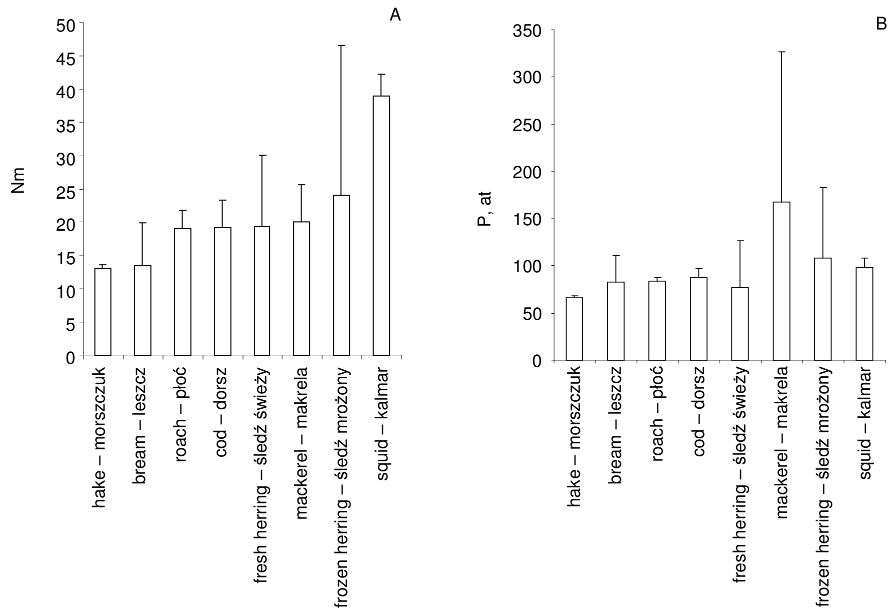

Fig. 3. Torque (A) and pressure (B) of starch vector extrusion with meat of various fish species and squid
Rys. 3. Porównanie wartości momentu obrotowego (A) i ciśnienia (B) w czasie ekstruzji nośników skrobiowych z mięsem różnych gatunków ryb i kalmara

Comparison of meat and "surimi" addition effects. The relationship between expansion index and amount of meat added to the formulations tested is illustrated in Figure 4. The changes depended primarily on the type of starch vector used. An increase in the amount of meat was observed to slightly change the expansion index of the extrudates containing the first starch vector, those extrudates containing the other vector showing a clearly reduced expansion index.

The results point to the importance of a starch vector used for creating porous structure in fried extrudates. Addition of animal protein usually reduced expansion, which was particularly evident in the samples containing pure potato starch. Changes in the expansion index in relation to the amount of meat are described by the following linear regression: $y = 5.95 - 9.6\ 10^{-2}\ x$, $R^2 = 0.969$, $\alpha = 0.005$, α – significance level.

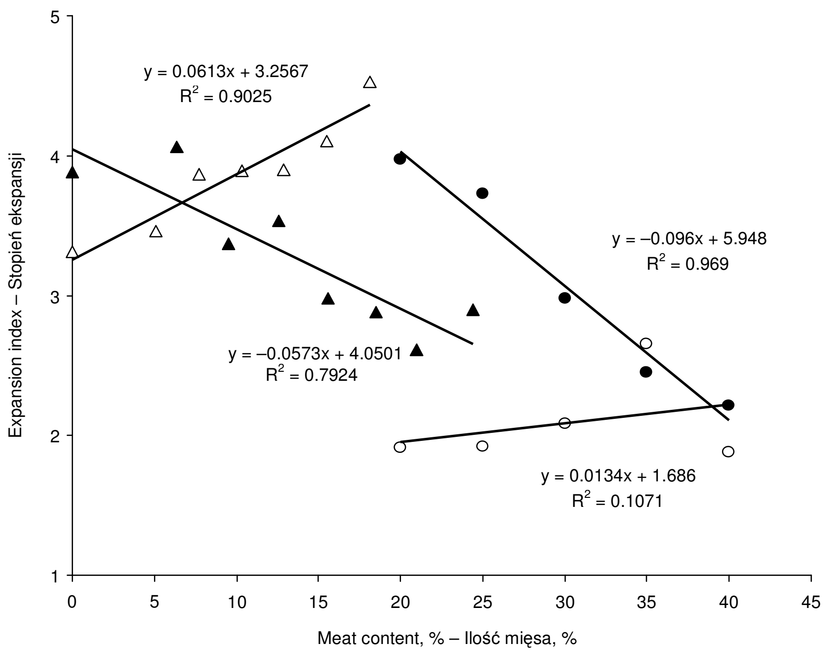

Fig. 4. Effects of melt meat content on starch-protein extrudate expansion: ▲ – corn grits + rice flour (1:1) + bream meat, △ – corn grits + rice flour (1:1) + bream "surimi", ● – Krupczatka-type wheat flour + rice flour + potato meal + potato puree (1:1.5:0.5:0.2) + squid tentacles, ○ – potato puree + Wrocławska-type wheat flour + rice flour (1:1:1) + squid tentacles

Rys. 4. Wpływ ilości mięsa w mieszaninie na stopień ekspansji ekstrudatów skrobiowo-białkowych: ▲ – kaszka kukurydziana + mąka ryżowa (1:1) + mięso z leszcza, △ – kaszka kukurydziana + mąka ryżowa (1:1) + surimi z leszcza, ● – mąka pszenna Krupczatka + mąka ryżowa + mączka ziemniaczana + puree ziemniaczane (1:1,5:0,5:0,2) + ramiona kalmara, ○ – puree ziemniaczane + mąka pszenna Wrocławska + mąka ryżowa (1:1:1) + ramiona kalmara

A trend towards reduced expansion with increasing amount of meat added was observed in the samples containing bream meat. The meat content was varied, at 2.9% increments, from 6.4 to 24.4%. The starch vector used was a 1:1 mixture of corn and rice grits (both having particles smaller than 1 mm). The formulations to be extruded showed identical moisture content (28% w/w).

Increasing bream meat contents in the extrudates was found to decrease the expansion index of the latter. The bream meat addition increase from 6 to about 24% resulted in the extrudate index decrease from about 4 to 2.9. The relationship is best described by the following linear equation: $y = 4.05 – 5.71\ 10^{-2}\ x$, $R^2 = 0.792$, $\alpha = 0.01$.

A similar relationship was obtained when corn grits were mixed with meat and cod "surimi" made from filleting wastes. The results (Fig. 5) failed to demonstrate any beneficial effect of meat washing on extrudate quality. The samples showed a higher density and a worse expansion, compared to those containing unwashed meat.

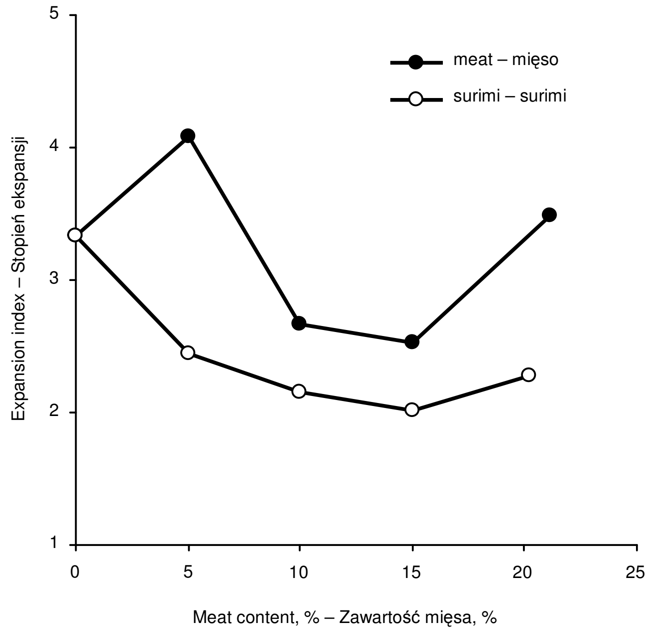

Fig. 5. Effects of cod filleting waste meat and surimi on extrudate expansion
Rys. 5. Wpływ dodatku mięsa i surimi z odpadów pofiletowych dorsza na stopień ekspansji ekstrudatów

This was perhaps related to a fairly high TMAO content in the cod meat and to a possible loss of functional properties by proteins subjected to the formaldehyde cross-linking [Kołakowski 1986]. Clayton [1992], who studied indirect extrusion of rice flour with addition of washed and dewatered cod meat, demonstrated that extrudate expansion following thermal treatment decreased with increasing meat content, regardless of the heating method applied.

Extruded were also starch-protein mixtures with bream "surimi". As opposed to the addition of bream meat, the bream "surimi" supplementation increased the expansion index from 3.46 to 4.53 as the "surimi" content increased from 5.1 to 18.1%. The starch vector consisted of a 1:1 blend of corn and rice grits, both with particle sizes smaller than 1 mm. The surimi content in melt was varied, at 2.6% increments, from 5.1 to 18.1%, the moisture being kept constant (about 28% w/w). The melt composition and the extrudate properties are summarized in Tables 3 and 4 and in Figure 4. The extrudate expansion was observed to increase with surimi content. The relationship can be described with a linear regression equation as: $y = 3.26 + 6.13\ 10^{-2}\ x$, $R^2 = 0.903$, $\alpha = 0.005$.

The results allow to presume that myofibrilar proteins, contributing most to the surimi, are more amenable than unwashed meat to texturisation by extrusion. Mineral salts, fat, non-protein substances, and water-soluble proteins combine to reduce the extrusion texturization effect. Their removal by, e.g., washing them away, as is the case in the surimi manufacture, improves extrudate expansion.

Table 3. Summary of data on bream meat-containing extrudates
Tabela 3. Zestawienie wyników dla ekstrudatów z dodatkiem mięsa z leszcza

Bream MDM MOM z leszcza	Percentage – Procent							
	0	6.4	9.5	12.6	15.6	18.5	21.4	24.4
a	1	2	3	4	5	6	7	8
Volume density before frying Objętość właściwa przed smażeniem $cm^3 \cdot g^{-1}$, $\pm\sigma_{n-1}$	0.732 ±0.03	0.704 ±0.02	0.720 ±0.04	0.719 ±0.02	0.747 ±0.03	0.734 ±0.04	0.740 ±0.04	0.728 ±0.02
Volume density after frying Objętość właściwa po smażeniu $cm^3 \cdot g^{-1}$, $\pm\sigma_{n-1}$	2.841 ±0.19	2.856 ±0.18	2.423 ±0.08	2.536 ±0.50	2.222 ±0.24	2.112 ±0.39	1.933 ±0.02	2.110 ±0.10
Expansion index Stopień ekspansji	3.88	4.06	3.37	3.53	2.98	2.88	2.61	2.90
Hardness before frying Twardość przed smażeniem N, $\pm\sigma_{n-1}$	134 ±55.9	109 ±31.3	118 ±44.9	135 ±28.8	86.5 ±31.4	132 ±86.8	89.7 ±25.7	113 ±81.8
Hardness after frying Twardość po smażeniu N, $\pm\sigma_{n-1}$	49.1 ±98.1	50.6 ±14.2	50.1 ±13.7	49.4 ±10.6	47.5 ±12.8	48.2 ±9.54	56.6 ±8.3	54.8 ±17.6

MDM – mechanically deboned meat.
MOM – mechanicznie odkostnione mięso.

Table 4. Summary of data on bream surimi-containing extrudates
Tabela 4. Zestawienie wyników dla ekstrudatów z dodatkiem surimi z leszcza

Bream surimi Surimi z leszcza	Percentage – Procent							
	0	6.4	9.5	12.6	15.6	18.5	21.4	24.4
a	1	2	3	4	5	6	7	8
Volume density before frying Objętość właściwa przed smażeniem $cm^3 \cdot g^{-1}$, $\pm\sigma_{n-1}$	0.685 ±0.028	0.710 ±0.018	0.709 ±0.03	0.712 ±0.02	0.751 ±0.13	0.715 ±0,01	0.716 ±0.05	0.685 ±0.028
Volume density after frying Objętość właściwa po smażeniu $cm^3 \cdot g^{-1}$, $\pm\sigma_{n-1}$	2.269 ±0.11	2.457 ±0.06	2.741 ±0.11	2.786 ±0.13	2.929 ±0.29	2.928 ±0.10	1.242 ±0.38	2.269 ±0.11
Expansion index Stopień ekspansji	3.312	3.461	3.866	3.888	3.900	4.100	4.528	3.312
Hardness before frying Twardość przed smażeniem N, $\pm\sigma_{n-1}$	100 ±29.0	103 ±21.3	167 ±57.3	159 ±96.2	131 ±56.9	147 ±40.6	149 ±19.5	100 ±29.0
Hardness after frying Twardość po smażeniu N, $\pm\sigma_{n-1}$	40.0 ±15.2	42.0 ±8.1	43.0 ±9.8	46.0 ±16.0	51.0 ±9.2	55.0 ±10.6	58.0 ±9.4	40.0 ±15.2

The extrudates were tested (the Warner-Bratzler test) for hardness before and after frying. Before frying, the extrudate hardness varied widely, depending on the surimi content. After frying, the variability was much narrower, the hardness showing a slight tendency to increase with the surimi content (Tables 3 and 4).

Protein fraction addition. The relevant results are shown in Figure 6. Non-soluble protein produced lower expansion indices, their values being independent of the screw rotational speed. The remaining fractions yielded higher expansion indices, the highest values being obtained with myofibrilar proteins at 100-150 rpm speed.

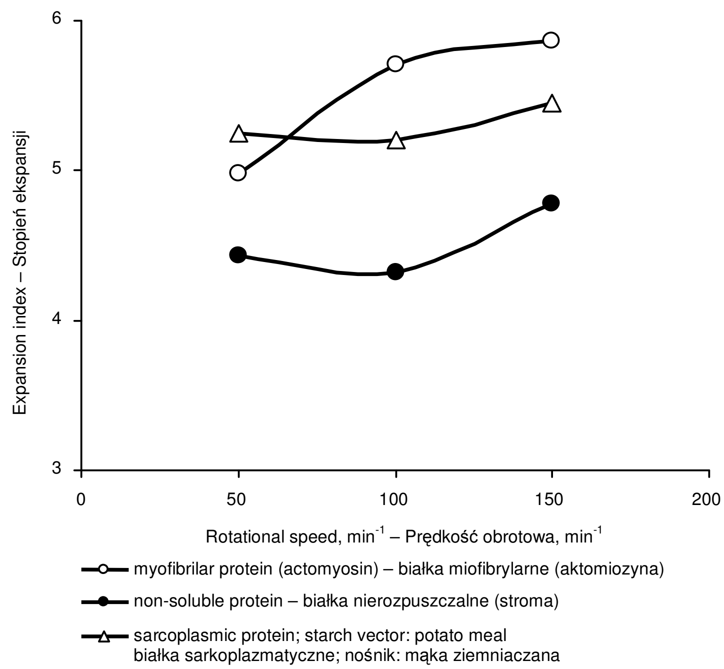

Fig. 6. Effects of rotational speed on expansion of starch extrudates supplemented with cod meat protein fractions
Rys. 6. Wpływ prędkości obrotowej na stopień ekspansji ekstrudatów skrobiowych z frakcjami białek mięsa dorsza

The results provide evidence on differential susceptibility of various proteins to texturization by extrusion. Myofibrilar proteins of cod proved most amenable to extrusion, yielding support to earlier findings from the bream "surimi"-supplemented samples.

Effects of initial thermal treatment. Expansion indices produced by extrudates containing cooked and raw squid meat were compared. Initial thermal treatment was found to only slightly increase the post-frying expansion. The highest expansion index was that shown by a sample containing squid meat pre-cooked for 2 min.

The results are summarised in the following arrangement:

Cooking time, min	Expansion index
0	3.87 ±0.012
1	3.93 +0.047
2	4.11 +0.076

Differences between the samples were statistically significant at $\alpha = 0.05$.

DISCUSSION

The research described showed warm extrusion to be applicable in manufacture of starch-protein extrudates containing fish and squid meat. The extrudate quality depended largely on the meat fat content. Lean fish proved more amenable to extrusion, expansion of the extrudates obtained being higher than that recorded in samples containing fatty fish meat. Extrusion of the first proceeded more smoothly and uniformly. These results and observations concur with those of Kahl [1981], Wiedmann and Strobel [1986], and Park et al. [1993] who found reduced expansion to accompany increasing fat contents. This is presumable a result of amylose-lipid complex formation and shearing strength reduction on extrusion.

Protein enrichment was found to reduce expansion, and to increase hardness, of the extrudates, which was also observed by other authors [Śmietana et al. 1985, Yamaguchi et al. 1988]. However, washed bream meat added to a starch vector increased the extrudate expansion, compared to samples lacking that addition. Thus, fish meat myofibrilar proteins may be regarded as more amenable to texturization than complete muscle proteins. This could be taken as evidence of an important role of sulphur bridges in protein texturisation.

Results reported by Paton and Spratt [1984], who added gluten to wheat starch to increase extrudate expansion, provide a certain analogy to those observations. It can be thus concluded that, in addition to fat, water-soluble proteins – both of plant and animal origin – reduce extrudate expansion, while myofibrilar protein of animal meat and vital gluten are a well-extrudable material.

Testing for effects of initial thermal treatment on expansion of squid tentacle meat-containing extrudates showed initial cooking for up to 2 min to have slightly (by about 6%) increased the extrudate expansion. That was most probably related to an increased content of myofibrilar proteins, resulting from losses of non-proteinaceous substances on cooking. The role of collagen thermolysis, facilitating protein-starch interaction, cannot be ruled out.

As measured with the Warner-Bratzler test, the post-frying extrudate hardness decreased with decreasing expansion index. Addition of both bream meat and bream surimi increased the post-frying extrudate hardness.

CONCLUSION

To sum up, it can be concluded that most of the animal protein vectors tested proved applicable in manufacture of starch-protein extrudates by warm extrusion cooking. Effects of those vectors on the final product quality depended on fish species, methods of meat separation and preservation, and methods of initial processing used. Lean fish supplied meat of better extrusion parameters than fat fish, fresh fish being superior in this respect to frozen fish. Fat was found to clearly reduce the extrudate quality, while washing of fish minces improved their applicability as components of formulations to be texturized by warm extrusion.

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OCENA PRZYDATNOŚCI MIĘSA RYB I KALMARA DO PRODUKCJI ŻYWNOŚCI TYPU „SNACK FOOD" METODĄ EKSTRUZJI POŚREDNIEJ

Streszczenie. Sprawdzono przydatność mięsa wybranych gatunków ryb morskich i słodkowodnych oraz kalmara do wytwarzania żywności typu „snack food" metodą ekstruzji pośredniej. Wytłaczano mieszaniny różnych surowców zbożowych z mięsem za pomocą jednoślimakowego ekstrudera laboratoryjnego typ 20DN (Brabender RFN). Mięso ryb chudych było lepszym materiałem do ekstruzji od ryb tłustych, a ryby świeże od mrożonych. Przemywanie mięsa wyraźnie poprawiało jego przydatność do przerobu metodą ekstruzji. Spośród przebadanych frakcji białkowych mięsa dorsza najbardziej przydatne do ekstruzji okazały się białka miofibrylarne.

Słowa kluczowe: ekstruzja, ryby, kalmar

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