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TECHNOLOGICAL UTILITY OF GUAR GUM AND XANTHAN FOR THE PRODUCTION OF LOW-FAT INULIN-ENRICHED MAYONNAISE

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Abstract. Effects of concentrations of guar gum, xanthan gum, and their mixture on selected physical and sensory properties of a model low-fat mayonnaise in which 50% of oil was replaced by inulin added in the form of Frutafit®Tex formula were studied. Viscosity and adhesion of the model mayonnaise was observed to increase with increasing concentrations of food gums; the highest increase was obtained when guar gum was applied alone, the lowest increase being a consequence of xanthan gum addition. All the inulin-enriched mayonnaises were stable if the food gum concentrations exceeded 0.11%. Food gum addition intensified the creamy colour of the model low-fat mayonnaise and slightly reduced the "fattiness effect" produced by the presence of inulin. Increased concentration of food gums increase elasticity and decreased fluffiness (air content) of the model low-fat inulin-enriched mayonnaises. The physical and sensory properties closest to those of the traditional mayonnaise were obtained by applying food gums at a concentration of 0.11%, in the form of guar gum-xanthan gum mixture. Addition of inulin to the model mayonnaise reduced its energy content by almost a half.

Key words: low fat mayonnaise, food gums, inulin

INTRODUCTION

Traditional mayonnaise is one of the oldest and most frequently used sauces. Its oil content is usually 70-80% [PN-A-86950], the energy content amounting to 2288 kJ/100 g [Kunachowicz et al. 2003]. However, the health-conscious consumers increasingly often seek low-energy foods; these are usually manufactured by reducing the fat content of traditional products. Production of low-fat sauces is possible only with certain specific additives which are capable of binding substantial amounts of water, and which may imitate some sensory and physical properties of fat [Krygier 1992, Waszkiewicz-Robak and Hoffmann 1999, Charles et al. 2000, Ye et al. 2004]. Food gums used in production of low-fat mayonnaise dissolve in water to form viscous solutions and, under appropriate

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conditions, coherent gels [Mandala et al. 2004]. When combined with other gums, they occasionally may show better functional properties than the sum of those properties measured separately [Kołakowski 1992]. Generally, gel-forming substances should produce a strong gel which will stabilize the product without producing an undesirable gluten consistence [McClements and Demetriades 1998], and will render the product's appearance close to that of traditional mayonnaise, accepted by consumers [Peressini et al. 1998]. Those newer and newer non-fat substances which should imitate functional properties of fat and reduce the energy level of a product are still being developed demonstrates the complexity of the problem and inadequacy of solutions used to date. One of such additives is inulin, an oligosaccharide obtained from chicory roots, commercially available as the Frutafit®Tex formula, which – in addition – is a probiotic and a soluble dietary fibre [Tomomatsu 1994, Gulewicz et al. 2003, Skowronek and Fiedurek 2003].

This work was aimed at optimizing the addition of selected food gums during the production of a model mayonnaise in which 50% of oil was replaced by inulin applied in the form of the commercial Frutafit®Tex formula.

MATERIALS AND METHODS

Raw materials

The study involved a model mayonnaise-type emulsion made from "Kujawski" rapeseed oil (Zakłady Tłuszczowe w Kruszwicy S.A., Poland), purchased in batches in retail as necessary, and food additives (fg-33 guar gum, xanthan gum, powdered egg yolk, citric acid, and Frutafit®Tex), purchased from Hortimex Ltd. (Konin, Poland). The raw materials were stored according to manufacturers' specifications, in tightly closed, light-proof containers, and used as necessary.

Model mayonnaise

The model low-fat mayonnaise was made according to a recipe for a traditional high-fat mayonnaise [PN-A-86950] in which 50% of the oil content was replaced by the fat substitute Frutafit®Tex; 1 g Frutafit®Tex was added instead of 4 g oil [www.hortimex.com.pl]. The model mayonnaise was enriched by adding guar gum and xanthan separately, or a 2:1 mixture of guar gum and xanthan gum; the additives were used at concentrations (w/w) of 0.1; 0.3; 0.5; 0.9; and 1.3% relative to the amount of water. The detailed composition of the model mayonnaises is given in Table 1. All the mayonnaise components were weighed to 0.001 g on a WPS 210/C analytical balance (Mechanika Precyzyjna, Radom) and were conditioned for 0.5 h at 35°C. Subsequently, dry components were added, one by one, to the measured amount of water and mixed vigorously with an MPW-302 laboratory homogenizer (Mechanika Precyzyjna, Warszawa) for 0.5 min at 14 thou. rpm. The homogenate was transferred to a round-bottom bowl of a Zelmer kitchen food processor, acidified by adding 1% citric acid, and blended again for 1 min at the highest speed of the processor. The samples were left for 30 min at 85°C and stirred occasionally for hydrocolloids to be completely hydrated. The resultant homogenous mass of the pre-mayonnaise, cooled down to 35°C, was blended with oil, added very slowly, until the entire amount of the oil was used. Each experimental series was accompanied by a parallel control sample, i.e., a high-fat mayonnaise (75% oil content).

Table 1. Composition of model mayonnaises
Tabela 1. Skład modelowych majonezów

Component Nazwa składnika	Component concentration, g/100 g mayonnaise Stężenie składnika, g/100 g majonezu					
	traditional mayonnaise majonez tradycyjny	low-fat mayonnaise majonez niskotłuszczowy				
Oil Olej	75	37.5	37.5	37.5	37.5	37.5
Water Woda	19	22.08	22.03	21.99	21.90	21.81
Inulin (Frutafit® Tex) Inulina (Frutafit® Tex)	–	9.375	9.375	9.375	9.375	9.375
Food gums* Gumy spożywcze*	–	0.022	0.066	0.111	0.199	0.287
Powdered egg yolk Żółtko jaja w proszku	6	6	6	6	6	6
Citric acid Kwas cytrynowy	0.03	0.03	0.03	0.03	0.03	0.03

*Guar gum, xanthan, or their mixture (2:1).
*Guma guar, ksantan lub mieszanka tych gum (2:1).

The following assays were performed in the model mayonnaise samples:

– viscosity, in a Rheotest 2 RV2 rotational viscometer, at shear stress z = 27 [dyne cm^{-3} × Skt] and shearing velocity Dr = 48.6 (s^{-1});

– adhesion, on a specially prepared laboratory balance [Tyszkiewicz 1969];

– bulk density (together with air pumped in during blending), by weighing 10 ml of model mayonnaise on the analytical balance (as above) at a constant temperature, identical for all the samples;

– active acidity, potentiometrically on a CI-316 pH-meter (Elmetron);

– emulsion stability after centrifugation in an MPW-350 laboratory centrifuge (Med. Instruments, Warszawa) for 10 min at 2500 rpm, after the samples had been stored for 24 h at 35 ±0.5°C. Emulsion stability was expressed as a ratio between the volume of the phase separated after centrifugation and the total emulsion volume [Leman and Kinsella 1989].

The sensory evaluation of the model mayonnaise consistence and colour was carried out by profiling, after appropriate descriptors of the mayonnaises produced had been established. The consistence was evaluated from two characteristics: fluffiness (air content) and elasticity, the colour being described as light yellow or creamy. The so-called fattiness effect of the model low-fat mayonnaises relative to that of the traditional product was taken into account as well. The intensity of the characters evaluated was assessed using a 5-score scale [Baryłko-Pikielna 1975]. The sensory evaluation was performed by a permanent 4-member panel consisting of evaluators who met the basic sensory sensitivity criteria as stipulated by the Polish Standard PN-ISO 6658.

Statistical treatment of the data was performed using the *Microsoft Excel 2000* software. Significance of differences was tested with 1-way analysis of variance at $\alpha = 0.05$.

Table 2. Comparison of selected physical properties of model traditional and low-fat mayonnaises; in the latter, 50% of oil was replaced by inulin added as Frutafit®Tex; effects of concentrations of guar gum, xanthan, or their mixture

Tabela 2. Porównanie wybranych właściwości fizycznych modelowego majonezu tradycyjnego oraz niskotłuszczowego, w którym 50% oleju zastąpiono inuliną dodaną w postaci preparatu Frutafit®Tex w zależności od stężenia gumy guar, ksantanu lub mieszanki tych gum

Mayonnaise type Rodzaj majonezu	Food gum concentration Stężenie gum spożywczych % ww	Guar gum Guma guar				Xanthan gum Guma ksantanowa				Guar gum-xanthan gum mixture (2:1) Mieszanka gumy guar i ksantanu (2:1)			
		viscosity cP lepkość cP	adhesion przylepność $N \cdot m^{-2}$	bulk density gęstość objętościowa $g \cdot cm^{-3}$	pH	viscosity cP lepkość cP	adhesion przylepność $N \cdot m^{-2}$	bulk density gęstość objętościowa $g \cdot cm^{-3}$	pH	viscosity cP lepkość cP	adhesion przylepność $N \cdot m^{-2}$	bulk density gęstość objętościowa $g \cdot cm^{-3}$	pH
Traditional mayonnaise Majonez tradycyjny	0	$1117.54^{a} \pm 28.29$	$94.2^{a} \pm 5.66$	$0.86^{a} \pm 0.00$	6.28	$1117.54^{a} \pm 28.29$	$94.2^{a} \pm 5.66$	$0.86^{a} \pm 0.00$	6.28	$1117.54^{a} \pm 28.29$	$94.2^{a} \pm 5.66$	$0.86^{a} \pm 0.00$	6.28
Low-fat mayonnaise Majonez niskotłuszczowy	0.022	$1131.69^{a} \pm 0.00$	$197.18^{b} \pm 7.07$	$0.42^{b} \pm 0.07$	6.37	$1230.71^{a} \pm 133.70$	$178.87^{b} \pm 5.66$	$0.67^{b} \pm 0.03$	6.44	$1103.40^{a} \pm 56.58$	$102.02^{a} \pm 0.99$	$0.57^{b} \pm 0.02$	6.49
	0.066	$1541.93^{b} \pm 0.00$	$283.84^{c} \pm 7.23$	$0.53^{c} \pm 0.08$	6.38	$1372.17^{a} \pm 84.87$	$197.83^{c} \pm 2.47$	$0.68^{c} \pm 0.05$	6.26	$1131.69^{a} \pm 92.40$	$98.75^{a} \pm 1.13$	$0.64^{c} \pm 0.01$	6.36
	0.111	$2079.48^{c} \pm 223.36$	$354.47^{d} \pm 5.66$	$0.64^{d} \pm 0.01$	6.41	$1655.09^{b} \pm 54.18$	$283.84^{d} \pm 1.13$	$0.83^{d} \pm 0.01$	6.26	$2602.88^{b} \pm 56.58$	$361.01^{b} \pm 8.99$	$0.72^{d} \pm 0.01$	6.49
	0.199	$3446.50^{d} \pm 102.88$	$818.16^{e} \pm 1.70$	$0.69^{e} \pm 0.01$	6.47	$2447.27^{c} \pm 84.88$	$254.41^{e} \pm 13.78$	$0.92^{e} \pm 0.02$	6,43	$2970.68^{c} \pm 0.00$	$677.55^{c} \pm 12.61$	$0.88^{e} \pm 0.01$	6.34
	0.287	$3451.65^{e} \pm 373.91$	$627.19^{f} \pm 5.66$	$0.84^{f} \pm 0.00$	6.30	$2942.39^{d} \pm 226.34$	$257.02^{f} \pm 3.93$	$0.86^{a} \pm 0.11$	6.24	$3890.18^{d} \pm 270.88$	$498.68^{d} \pm 13.07$	$0.90^{f} \pm 0.01$	6.30

NB. Significance of differences was tested between data for traditional mayonnaise and low-fat mayonnaise with different concentrations of food gums; values denoted by identical letter are significantly different at $\alpha = 0.05$. pH value is an arithmetic mean of three measurements.

Uwaga. Istotność różnic liczono pomiędzy próbami majonezu tradycyjnego i majonezu niskotłuszczowego zawierającego różne stężenie gum spożywczych. Wartości liczbowe oznaczone w kolumnach taką samą literą są względem siebie statystycznie istotne na poziomie $\alpha = 0,05$. Wartość pH jest średnią arytmetyczną z trzech równoległych pomiarów.

RESULTS AND DISCUSSION

The model low-fat mayonnaise in which 50% of the oil amount was substituted by inulin in the form of the commercially available Frutafit®Tex formula was prepared with different contents of food gums to find out which gum concentration would be optimal. The experiment involved simple methods of measuring physical and sensory properties of the mayonnaises. The methods used allowed to observe that addition of a food gum to the model low-fat mayonnaise changed the appearance and physical properties of the mayonnaise, relative to the traditional product, and that the changes depended both on the concentration and the type of hydrocolloids used.

An increase in food gum concentration was found to be accompanied by an increase in the viscosity of the colloid-emulsion system, regardless of whether the hydrocolloids were added separately or as a mixture. However, the changes became significant only when the gum concentration exceeded 0.066% (Table 2; Fig. 1). Kołakowski [1992] contended that even small (0.1-0.5%) doses of hydrocolloids clearly enhance rheological properties of food products because the viscosity increases geometrically with increased hydrocolloid concentration. The best effect in the manufacture of low-fat mayonnaises with hydrocolloids is obtained with a food gum mixture consisting of 0.4-0.6% guar gum and 0.1% xanthan gum, or with 0.2-0.6% xanthan gum only [Zalewski 1997]. On the other hand, Stauffer [2001] recommended the use of soluble gums at concentrations of 0.05-0.3%. The analyses performed allowed to conclude that, in the inulin-enriched model mayonnaise, it was sufficient to add a food gun at a concentration of 0.022% to render the mayonnaise viscosity similar to that of the traditional product (Fig. 1). Moreover, the model low-fat mayonnaises containing xanthan gum showed

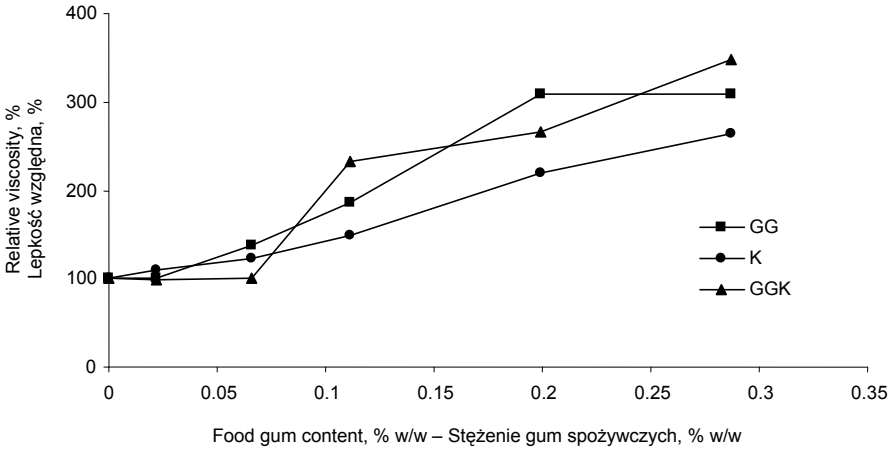

Fig. 1. Effects of concentrations of guar gum (GG), xanthan gum (K) or their mixture (GGK) on viscosity of model low-fat mayonnaise with 50% of oil replaced by inulin applied as Frutafit Tex. (expressed as % relative to traditional mayonnaise)
Rys. 1. Wpływ stężenia gumy guar (GG), ksantanu (K) lub mieszanki tych gum (GGK) na lepkość modelowego majonezu niskotłuszczowego, w którym 50% oleju zastąpiono inuliną dodaną w postaci preparatu Frutafit Tex. (wyrażone jako procent w stosunku do majonezu tradycyjnego)

a lower viscosity and adhesion than the guar gum-enriched mayonnaises and those containing a guar gum-xanthan mixture at concentrations higher than 0.111% (Figs 1, 2). Consequently, xanthan gum can be regarded as a very good filling in low-fat mayonnaises, as it may form medium-viscosity solutions. In addition, xanthan gum enhances the emulsifier effect because it is water-soluble and blocks coalescence of oil drops [Xie and Hettiarachchy 1997]. Hennock et al. [1984] are of the opinion that xanthan gum

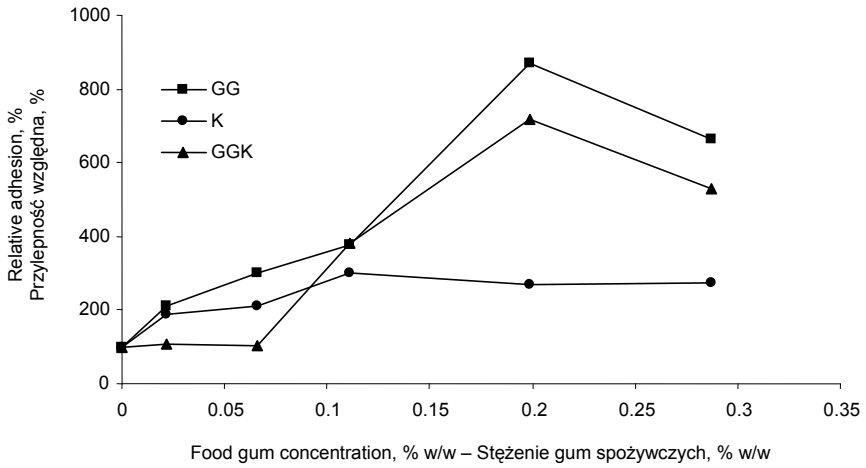

Fig. 2. Effects of concentrations of guar gum (GG), xanthan gum (K) or their mixture (GGK) on adhesion of model low-fat mayonnaise with 50% of oil replaced by inulin applied as Frutafit Tex. (expressed as % relative to traditional mayonnaise)
Rys. 2. Wpływ stężenia gumy guar (GG), ksantanu (K) lub mieszanki tych gum (GGK) na przylepność modelowego majonezu niskotłuszczowego, w którym 50% oleju zastąpiono inuliną dodaną w postaci preparatu Frutafit Tex. (wyrażone jako procent w stosunku do majonezu tradycyjnego)

stabilises the emulsion in two ways. Some of the xanthan gum is absorbed in the oil-water interface, which decreases surface tension and reduces the oil drop size, while the other part of xanthan gum is maintained in its liquid crystalline phase and adsorbs oil drops in the microgel matrix. Low-fat food manufacturers try to reduce the mayonnaise oil content as much as possible. However, reducing the amount of oil in a mayonnaise diminishes the amount of oil drops; consequently, their interactions are weakened and the emulsion stability is impaired [Depree and Savage 2001]. Low-fat emulsions separate into layers by gravitational forces, as predicted by the Stokes Law. Those emulsions containing less than 40% (w/w) of oil were found to be highly unstable because they separated into layers when stored for a day at 5°C [Franco et al. 1995]. Low-fat emulsion stability can be increased by reducing the oil drop size, which, however, may impart a slightly creamy coloration on the product, or by increasing viscosity of the continuous phase by using thickeners [McClements and Demetriades 1998]. This study examined effects of increased viscosity of the continuous phase at unchanged diminution and dispersion of oil drops. It turned out that all the model low-fat inulin-enriched mayonnaises showed 100% stability when the food gum concentration did not drop below 0.111%, regardless of whether the gums were applied separately or jointly as

a mixture. However, admixture of other thickeners, e.g., modified starch, may render a low-fat mayonnaise more stable than the traditional high-fat product [Depree and Savage 2001]. An increase in food gum concentration within the range of 0.022-0.287% produced no change in active acidity (pH) of the model low-fat inulin-containing mayonnaise, relative to the traditional product. All the model mayonnaises showed similar pH values which ranged within 6.28-6.49 (Table 2). Depree and Savage [2001] contend that mayonnaise is stable if pH is close to the mean value of the isoelectric point of the emulsifier used to produce the mayonnaise.

In addition, a comparison between the traditional mayonnaise and the model low-fat product with inulin replacing 50% of oil showed the low-fat mayonnaise to have a distinctly different appearance. The characteristically yellow coloration typical of the traditional mayonnaise disappeared, the low-fat product assuming a delicate light-creamy hue the intensity of which increased with increasing concentrations of the gums (Fig. 3).

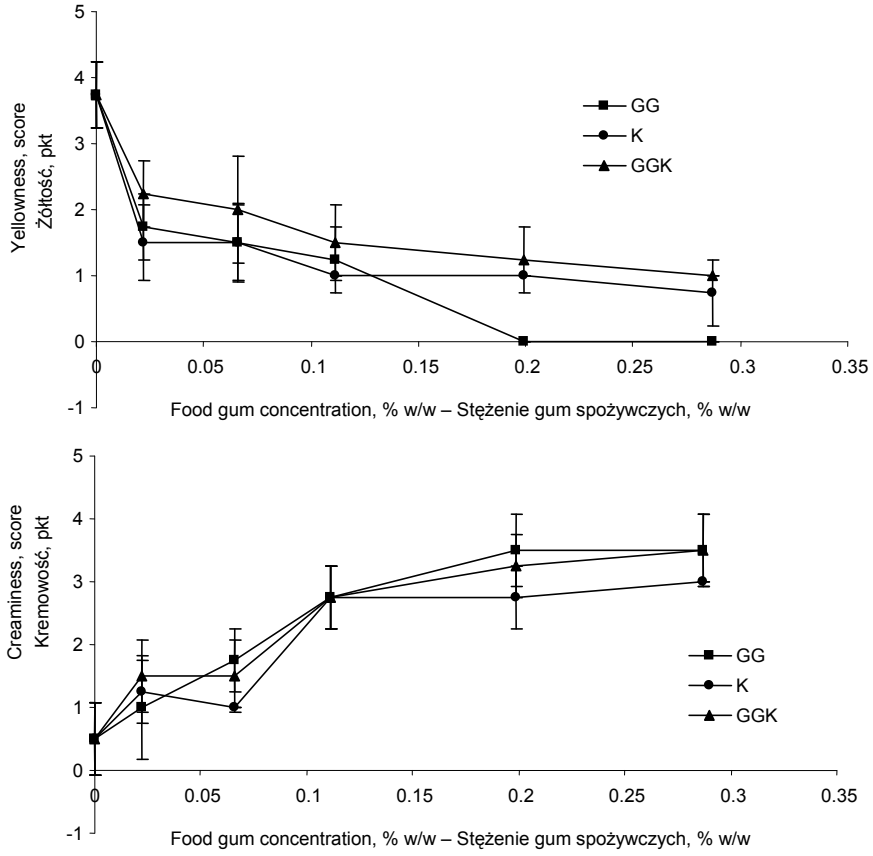

Fig. 3. Effects of concentrations of guar gum (GG), xanthan gum (K) or their mixture (GGK) on colour changes of model low-fat mayonnaise with 50% of oil replaced by inulin applied as Frutafit Tex.

Rys. 3. Wpływ stężenia gumy guar (GG), ksantanu (K) lub mieszanki tych gum (GGK) na zmiany barwy modelowego majonezu niskotłuszczowego, w którym 50% oleju zastąpiono inuliną dodaną w postaci preparatu Frutafit Tex.

Yellowness of the traditional mayonnaise scored 3.5 points, while yellowness of the low-fat product with as little as 0.066% of food gums scored 1.8, i.e., almost a half less. The Frutafit®Tex manufacturer points out that inulin addition to a food product imparts a delicate satin-like glow to it, the so-called "fattiness effects" which, in a low-fat mayonnaise, may be favourably perceived by consumers. Therefore the evaluation panelists were asked how the "fattiness effect" of the model low-fat mayonnaise with inulin replacing 50% of oil changed with changing gum addition. The "fattiness effect" was evident in all the low-fat inulin-enriched mayonnaises; its intensity decreased with increased gum concentration, particularly in those samples containing a guar gum-xanthan gum mixture, even by an average of 50%, relative to the traditional mayonnaise (Fig. 4).

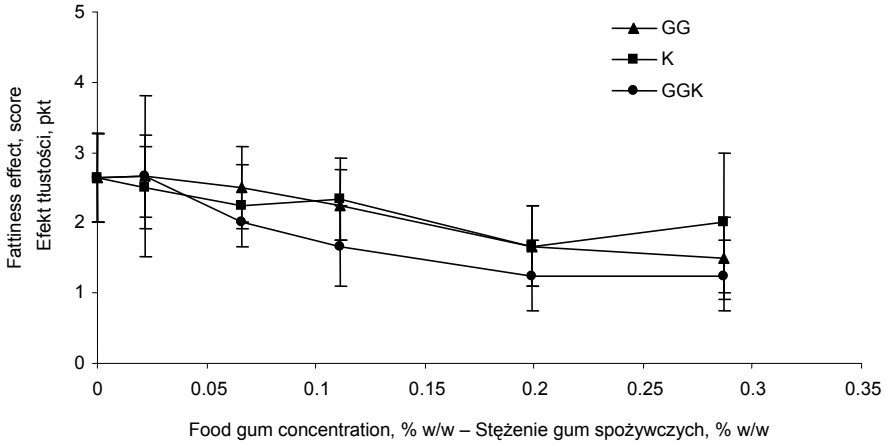

Fig. 4. Effects of concentrations of guar gum (GG), xanthan gum (K) or their mixture (GGK) on fattiness effect of model low-fat mayonnaise with 50% of oil replaced by inulin applied as Frutafit Tex.
Rys. 4. Wpływ stężenia gumy guar (GG), ksantanu (K) lub mieszanki tych gum (GGK) na efekt tłustości modelowego majonezu niskotłuszczowego, w którym 50% oleju zastąpiono inuliną dodaną w postaci preparatu Frutafit Tex.

In terms of the "fattiness effect", samples of the model low-fat mayonnaise containing up to 0.066% gums were most similar to the traditional product. If, then, a low-fat mayonnaise with inulin replacing 50% of oil is expected to resemble the traditional product in its colour, guar gum, xanthan gum, or their mixture should be added at a concentration not exceeding 0.066%.

Appropriate selection of food gum concentration is important also from the standpoint of the low-fat mayonnaise consistence which, if too much gum is added, may become elastic-gummy; if too little gum is applied and not the entire amount of water is permanently bound, the mayonnaise may appear as an aerated fluffy mass. Therefore elasticity of the model mayonnaises was examined in relation to the concentration and type of the food gum added; the degree of aeration was evaluated by visually assessing the fluffiness and by measuring the model sample bulk density. Those mayonnaises containing 0.022% of food gums were clearly most aerated, showed the lowest bulk density, and their elasticity scored an average of 0.5 point (Figs 5, 6). An increase in the

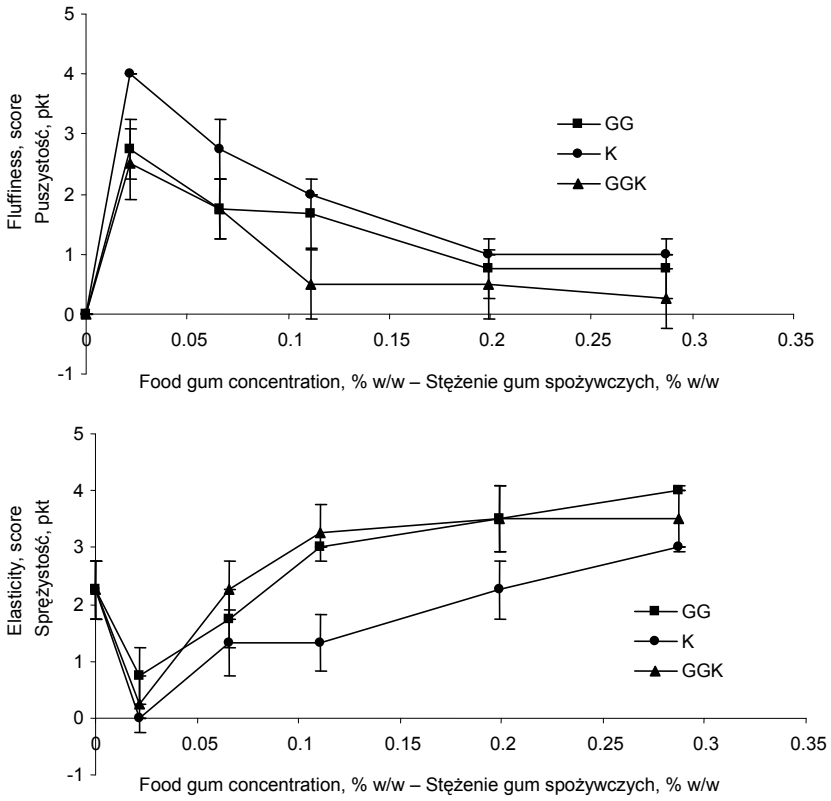

Fig. 5. Effects of concentrations of guar gum (GG), xanthan gum (K) or their mixture (GGK) on consistence of model low-fat mayonnaise with 50% of oil replaced by inulin applied as Frutafit Tex.
Rys. 5. Wpływ stężenia gumy guar (GG), ksantanu (K) lub mieszanki tych gum (GGK) na konsystencję modelowego majonezu niskotłuszczowego, w którym 50% oleju zastąpiono inuliną dodaną w postaci preparatu Frutafit Tex.

gum concentration to 0.111% distinctly increased elasticity, while decreasing fluffiness of the model low-fat mayonnaises with inulin replacing 50% of oil (Fig. 5). A further increase in the gum concentration hardly affected the properties studied, the slight differences between the samples being mostly non-significant (Fig. 5).

To sum up, the physical and sensory properties of the low-fat mayonnaise with 50% of oil replaced by inulin were most similar to the properties of the traditional product when the food gums were applied at the concentration of 0.111%, preferably as a mixture, which made it possible to halve the energy content of the mayonnaise (Table 3). Adding such a small amount of food gums to the model mayonnaise proved sufficient most probably because inulin forms viscous aqueous solutions already at low concentrations [Devereux et al. 2003].

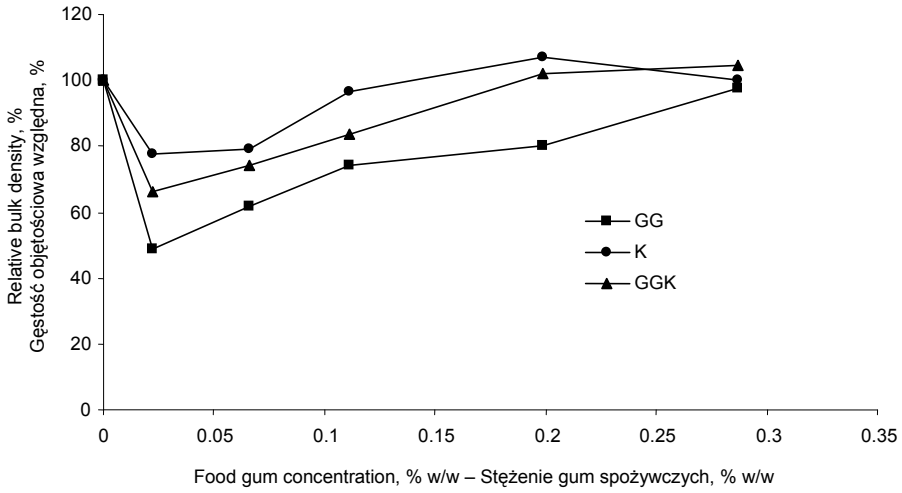

Fig. 6. Effects of concentrations of guar gum (GG), xanthan gum (K) or their mixture (GGK) on bulk density of model low-fat mayonnaise with 50% of oil replaced by inulin applied as Frutafit Tex. (expressed as % relative to traditional mayonnaise)
Rys. 6. Wpływ stężenia gumy guar (GG), ksantanu (K), lub mieszanki tych gum (GGK) na gęstość objętościową modelowego majonezu niskotłuszczowego, w krórym 50% oleju zastąpiono inuliną dodaną w postaci preparatu Frutafit Tex. (wyrażone jako procent w stosunku do majonezu tradycyjnego)

CONCLUSIONS

1. Viscosity and adhesion of the model low-fat inulin-enriched mayonnaise increased with increasing concentration of food gum, particularly when the concentration of guar gum alone or in a mixture with xanthan gum exceeded 0.11%.

2. Addition of food gums intensified the creamy colour of the model low-fat mayonnaise and slightly diminished its "fattiness effect" produced by the presence of inulin.

3. Those mayonnaises with less than 0.11% of food gums were clearly most aerated (fluffy) and showed the lowest bulk density, the elasticity increasing slightly at higher food gum concentrations.

4. Addition of 0.11% of the guar gum-xanthan gum mixture rendered the mayonnaise most similar to the traditional product in terms of its physical and sensory properties.

5. Substitution of oil by inulin reduced the energy content of the model mayonnaise by almost 50%.

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PRZYDATNOŚĆ TECHNOLOGICZNA GUMY GUAR I KSANTANU DO PRODUKCJI MAJONEZU NISKOTŁUSZCZOWEGO Z DODATKIEM INULINY

Streszczenie. Zbadano wpływ stężenia gumy guar, ksantanu i mieszanki tych gum na wybrane właściwości fizyczne i organoleptyczne modelowego majonezu niskotłuszczowego, w którym 50% oleju zastąpiono inuliną dodaną w postaci preparatu Frutafit®Tex. Zauważono, że lepkość oraz przylepność modelowego majonezu rosła wraz ze wzrostem stężenia gum spożywczych, najbardziej gdy dodawano samą gumę guar, a najmniej – kiedy stosowano ksantan. Wszystkie majonezy z dodatkiem inuliny były stabilne, jeżeli stężenie gum spożywczych wynosiło powyżej 0,11%. Dodatek gum spożywczych intensyfikował kremową barwę modelowego majonezu niskotłuszczowego i nieznacznie zmniejszał „efekt tłustości" wywołany obecnością inuliny. Wzrost stężenia gum spożywczych zwiększał sprężystość i obniżał puszystość (napowietrzenie) modelowych majonezów niskotłuszczowych z dodatkiem inuliny. Najbardziej zbliżone do majonezu tradycyjnego właściwości fizyczne i organoleptyczne uzyskano, stosując 0,11% gum spożywczych, które dodawano w postaci mieszanki gumy guar i ksantanu. Wprowadzenie inuliny do modelowego majonezu obniżało prawie o połowę jego wartość energetyczną.

Słowa kluczowe: majonez niskotłuszczowy, gumy spożywcze, inulina

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