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COMPARISON OF FUNCTIONAL PROPERTIES OF SELECTED VEGETABLE HYDROCOLLOIDS AND EMULSIFIERS

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Key words: hydrocolloids, starch, emulsifiers, foam formation, frimulsion.

Physico-chemical properties of selected stabilizing substances, namely natural hydrocolloids, natural and modified starches and natural and synthetic emulsifiers, were studied. The emulsifiers are prominent among the investigated stabilizing substances in view of their high foam formation and fat emulsification capacities. The frimulsion-type hydrocolloids exhibit a similar or sometimes even higher emulsifying effectiveness greater emulsion stability. None of the studied starches displayed emulsifying properties, and they stabilize solutions by increasing their viscosity, a process due to starch pasting.

INTRODUCTION

The use of stabilizing substances (hydrocolloids and emulsifiers) in food technology is becoming increasingly widespread and diverse, and is aimed primarily at improving rheological properties of products, facilitating technological processes, obtaining analogues of natural products, substitution of more expensive or unavailable components, and at producing low-caloric foodstuffs [1, 3, 16-18].

The applicability of hydrocolloids and emulsifiers is determined by their functional properties by which we mean the physico-chemical and sensory properties of preparations affecting the technological and qualitative features of the food products to which they were added (consistence, water retention capacity, etc.) [10, 15].

The following functional properties of stabilizers are of the greatest significance from the viewpoint of their technological applicability: capacity to dissolve or suspend in water and fat, viscosity, gel forming capacity,

degree of water and fat adsorption, the capacity to form and stabilize emulsion, and foam producing capacity [2, 7, 10, 13-15].

The studies performed to date focused mainly on comparing properties of substances belonging to one group (e.g. of milk proteins preparations), and that mainly with the view of using them as meat substitutes or additives improving the quality and nutritive value of products [6, 10, 13-16]. The available literature does not provide data enabling comparisons of stabilizing substances belonging to different groups, in spite of the constantly increasing number of newly marketed preparations. It thus seemed advisable to compare the most important physico-chemical properties of stabilizing substances used in Poland and elsewhere in the world in order to promote their correct application.

MATERIAL AND METHODS

The following stabilizing substances were investigated:

1. Natural hydrocolloids obtained from sea-weeds extracts locust bean gum, guar gum.

— frimulsions; 10, San, Dry and N produced with carob and guar gums, possibly containing other natural hydrocolloids (composition not disclosed by the manufacturers), from IFAG Interfrimulsion GmbH:

— carrageen CJ Denmark;

— panisol produced with carob gum and κ -carrageenate, from Kirk (Denmark);

2. Natural starches:

— potato starch from the potato processing plant in Trzemieszno;

— wheat and maize starch from Stärkefabrik-Ahlen (Westf.), West Germany;

— Poznań wheat flour, type 650, from the grain mill in Białoleka;

3. Modified potato starches:

— phosphate starches PC-3, PC-7.5, PC-10 and PA-5 from the potato processing plant in Niechlów;

— starches oxidized with sodium hypochlorite: gelatine-like (gel forming) starch, starches with various degrees of oxidation (denoted A, B and C) and thickener S — all from the potato processing plant in Luboń near Poznań;

4. Emulsifiers:

— natural: rapeseed and soybean lecithin from the 15 Grudnia Fat Processing Plant in Warsaw;

— synthetic emulsifiers with various monoglycerides contents: Dimodan PM (90%) from Denmark, Polynol A (76%) from Czechoslovakia, and emulsifier MS (41%) from the fat processing plant in Gdańsk, Poland.

Emulsifying capacity was investigated by Swift's method as modified

by Kwaśniewska [6]; the capacity to stabilize the emulsion after heating to 80°C by the method of Inklaar and Fortuin (after [10]); solution and suspension capacity in water at 20°C according to [8]; viscosity of 1% solutions (at $Dr = 437.4 \text{ s}^{-1}$) and 10% solutions (at $Dr = 145.8 \text{ s}^{-1}$) was measured with a Rheotest 2-50 Hz type RV-2 rotary viscosimeter; water and fat adsorption was determined by the centrifuge method (after [10]), foam capacity and foam stability at 20°C was studied with Yasumatsu's method after dissolving preparations at 20 and 80°C and cooling to the measurement temperature (after [10]); gel formation capacity was assessed with the ADM method (visually or with the use of a Labor penetrometer) in 1%, 5% and 15% solutions and in the case of modified starches also in 8% solutions with and without additions of 25% sugar and 0.5% citric acid (after [10]). Results of penetrometric evaluations were expressed in degrees of penetration. In visual assessments the following descriptions were employed: "—" no gel, "+" soft gel, "++" moderately hard gel, "+++ " very hard gel.

RESULTS AND DISCUSSION

The physico-chemical properties of the studied stabilizers are presented in Tables 1 and 2 and in Figs 1-4. The properties vary considerably, between groups as well as in the individual groups themselves. A characteristic feature of hydrocolloids is that they dissolve or disperse in cold or hot water. Among the studied polysaccharides the greatest ability to dissolve or disperse in water at 20°C was demonstrated by frimulsions and carrageen CJ. Phosphate starches possessed this capability to a much smaller extent, while Panisol, natural starches and starches modified by oxidation with sodium hypochlorite dissolved or dispersed only minimally. Since none of the investigated starches was fully soluble in low temperatures, it is not advisable to use them as thickeners in instant desserts; they must previously be pasted by cooking.

The various hydrocolloid groups differ considerably with regard to water adsorption. The highest figures were obtained for preparations of the frimulsions group. Phosphate starches and thickener S are capable of adsorbing large amounts of water and this, together with their moderate solubility in cold water, justifies their inclusion in the category of so called swelling starches. Water adsorption in the remaining modified and natural starches is minimal.

Important properties of stabilizers affecting the structure of food products to which they are added are viscosity and gel forming capacity in water solutions. The viscosity of 1% and 10% solutions of the studied hydrocolloids is illustrated in Fig. 1. The most viscous 1% solutions are those of frimulsions (10-25 times greater viscosity than of the remaining

Table 1. Physico-chemical properties of selected natural polysaccharides

Polysaccharide	Emulsifying capacity (cm ³ oil) (100 mg preparation)	Emulsion stability (%)	Capacity to dissolve and disperse in water at 20°C (%)	Water adsorption (cm ³ /g)	Fat adsorption (cm ³ /g)	Ability to gelate solutions (visual assessment)			Foam forming capacity (cm ³)	
						1%	5%	15%	20°C	80°C*)
Frimulsion 10	10.1	61.8	100	36.2	1.00	-	+	nm.	0.75	0
Frimulsion San	16.0	63.6	100	35.3	0.70	-	++	nm.	0	1.0
Frimulsion N	11.0	100.0	90	29.9	0.75	++	+++	nm.	1.0	0
Frimulsion Dry	14.0	81.8	100	26.6	0.80	+	+++	nm.	0	0
Carragheen CJ	0	72.7	91	7.95	1.20	+	+++	nm.	1.75	38.0
Panisol	6.5	2.2	1.5	4.54	0.99	+	+++	nm.	5.5	1.0
Natural starches:										
potato starch	0	0	1.7	0.63	0.80	-	+	+++	0	0
wheat starch	0	0	2.1	0.81	1.19	-	+	++	0	0
maize starch	0	0	2.0	0.82	1.00	-	+	+++	0	2
Wheat flour, type 650	0	0	1.9	0.81	1.00	-	+	++	22	29

„-“ no gel, „+“ soft gel, „++“ moderately hard gel, „+++“ very hard gel, „nm“ not measurable

*) Samples dissolved at 80°C and cooled down to 20°C

T a b l e 2. Physico-chemical properties of selected modified starches

Starch	Emulsifying capacity (cm ³ oil/100 mg preparation)	Emulsion stability (%)	Capacity to dissolve and disperse in water at 20°C (%)	Water adsorption (cm ³ /g)	Fat adsorption (cm ³ /g)	Ability to gelate solutions (visual assessment)		
						8%	8% solution with 25% sugar and 0.5% citric acid	15%
Phosphate starch:								
PC-10	0	0	21	11.40	1.50	+	ns	+
PA-5	0	0	49.4	4.60	1.45	+	ns	++
PC-3	0	0	8.0	12.10	1.45	+	ns	++
PC-7,5	0	0	15.0	11.70	2.50	++	ns	++
Starches oxidized with sodium hypochlorite								
Gelatine-like	0	0	0.3	0.76	0.70	++	++	+++
A	0	0	5.0	0.82	0.60	++	+++	+++
B	0	0	2.4	0.79	0.50	++	+++	+++
C	0	0	0.5	0.83	0.50	++	++	+++
Thickener „S”	0	0	48.5	9.28	1.80	++	++	+++

„+” soft gel, „++” moderately hard gel, „+++” very hard gel, „ns” not studied

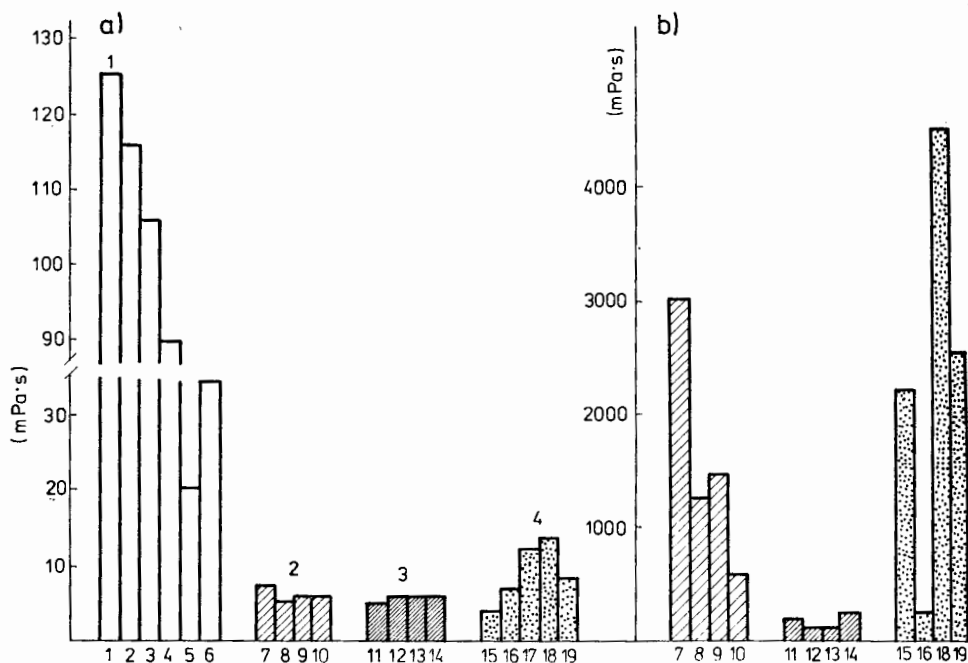


Fig. 1. Viscosity of 1% (a) and 10% (b) solutions of studied hydrocolloids

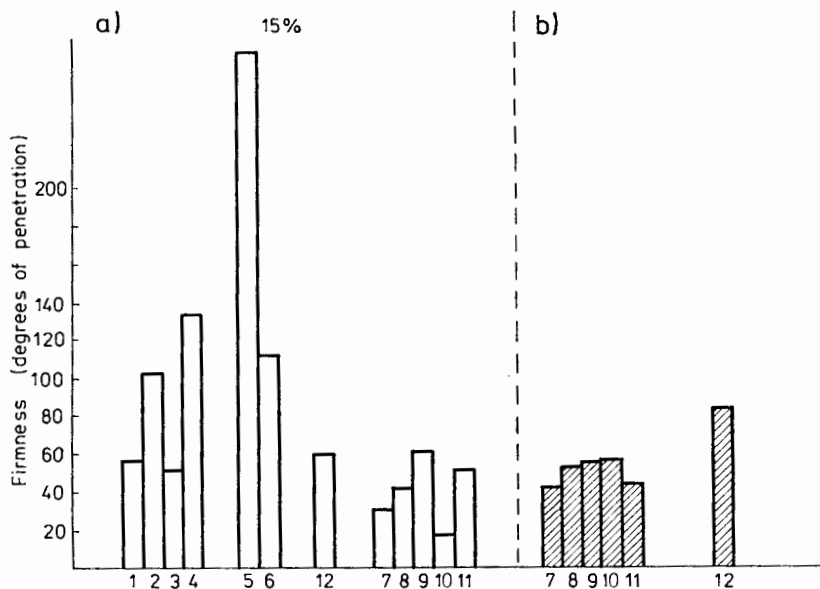


Fig. 2. Gel formation capacity of natural and modified starches in 15% water solutions a) and 8% water solutions containing sugar and citric acid b) in comparison to gelatine power of gelatine

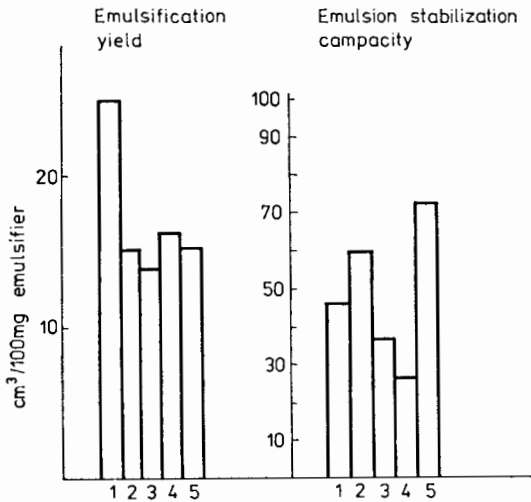


Fig. 3. Emulsifying properties of emulsifiers; 1—Dimodan PM, 2—Polynol A, 3—emulsifier MS, 4—soybean lecithin, 5—rapeseed lecithin

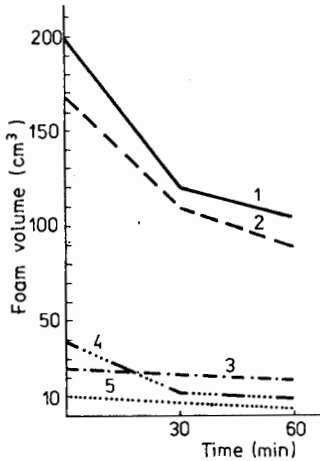


Fig. 4. Foam formation capacity of 1% emulsifier solutions (emulsifiers dissolved at 80°C) and foam stability

polysaccharides). The viscosity of 10% frimulsions solutions is so great that it could not be measured with the available viscosimeter. These results are indicative of the excellent thickening properties of frimulsions, thanks to which the additions of these preparations in practice never exceed 1%.

The viscosity of 1% solutions of the investigated natural and phosphate starches is fairly low (4.8–6.7 mPa·s). Oxidized starches are slightly more viscous. At 10% concentration, the modified phosphate starches display a very low viscosity, lower than that of natural starches and starches modified with sodium hypochlorite. Such a low viscosity of phosphate

starches produced in Poland is evidence of their poor quality and probably also of a faulty estrification process. The phosphate esters of starch obtained in many countries, and previously also in the Institute of Human Nutrition of the Agricultural Academy in Warsaw [3, 12] are characterized by very high viscosity, exceeding several times the viscosity of natural starches. The latter phosphate starches moreover dissolve or swell very well in water without previous heating.

The gel forming capacity of the studied polysaccharides varies considerably, and depends on their concentration, on the kind of polysaccharide and on the applied additions of taste enhancing substances (citric acid and sugar). 1⁰/o polysaccharide solutions display no or fairly low gel forming capacity (frimulsion N, Dry, carragheen CJ, panisol), being admissible for use with only small quantities of these preparations, usually below 1⁰/o, [9, 17]. Hence they cannot be used as gel forming agents in products with fairly hard gel, such as jellies. Since the gel forming capacity of starches used to produce desserts is significantly affected by the presence of components such as sugar and citric acid, it was studied in oxidized starch in solutions with and without 25⁰/o of sugar and 0.5⁰/o of citric acid (quantities usually added to desserts). Analyses were performed with 8⁰/o solutions (maximum concentration allowed by Polish sanitary regulations). In addition, the gel forming capacity of these systems was compared with the respective capacity of 15⁰/o starch solutions and analogous gelatine solutions (Fig. 2). It was found that oxidized starches in 8⁰/o solutions without sugar and citric acid usually give weaker, running gels, unmeasurable penetrometrically. The gelation power of 8⁰/o solutions with the two additions is much greater (43.4-54.3 degrees of penetration), comparable with the gelation ability of 15⁰/o solutions, i.e. solutions of almost twice greater starch concentration. However, gels obtained from starches oxidized with sodium hypochlorite are characterized by a more fragile texture (breaking apart under pressure), markedly different from the dense and elastic texture typical for gelatine gels. Thus, it is not possible to obtain full quality gels using only gelatine-like starches and other starches oxidized with hypochlorite. In view of the short supply of gelatine in Poland, it is advisable to use suitable combinations of gelatine and gel-forming starches in the production of desserts.

Fat adsorption by the studied polysaccharides varies considerably, from 0.5 to 2.5 cm³/g, the highest figures being obtained for phosphate starches (1.45-2.5 cm³/g). In the remaining polysaccharides, except for thickener S, fat adsorption is similar (0.5-1.2 cm³/g).

The fundamental features of emulsifiers are the capacity to emulsify fats and to stabilize the emulsions. These properties are also displayed by some hydrocolloids.

The capacity of synthetic emulsifiers to emulsify fat depends on monoglycerides content. The greatest emulsifying capacity among the studies

emulsifiers was exhibited by Dimodan PM containing 90% monoglycerides. This capacity was much less pronounced in emulsifiers Polynol A (76% monoglycerides) and MS (41% monoglycerides). A fairly high emulsifying effectiveness higher than that of Polynol A and emulsifier MS, is displayed by rapeseed and soybean lecithin (Fig. 3).

Of the analysed polysaccharides only frimulsion and panisol are capable of emulsifying fat. The fat emulsification yield for these preparations is lower (frimulsion 10, N, panisol) or the same as of emulsifiers (frimulsion San, Dry). Frimulsions and carragheen CJ are highly effective in stabilizing the emulsion following its heating to 80 C, more so than emulsifiers. This shows them to be very useful as emulsion stabilizers in products intended for thermal treatment. The present studies of emulsifying properties of frimulsions are in agreement with reports in the literature [9, 14]. Natural and modified starches do not exhibit emulsifying capabilities.

The foam producing capacity of stabilizers and the stability of the obtained foam are particularly important in the case of whipped desserts. The two properties vary considerably in the studied substances, and they also depend on the temperature of preparation dissolution (20 and 80°C). Only 1% solutions of carragheenate CJ, panisol and wheat flour produced unstable foam (2, 5 and 22 cm³, respectively). Natural and modified starches failed to produce foam. Compared with polysaccharides, a very high foam producing capacity was demonstrated by synthetic emulsifiers (after dissolution at 80°C). This capacity increases with the increasing content of monoglycerides, and the obtained foam is fairly stable. Much less foam was received by whipped rapeseed and soybean lecithin solutions (Fig. 4).

The performed studies demonstrated the possibility of comparing functional properties of preparations belonging to various groups, both among hydrocolloids and the chemically very different hydrocolloids and emulsifiers.

Comparisons of properties of various groups of preparations ought to be very helpful in selecting agents stabilizing food products, indicating possibilities of replacing some substances by others (e.g. ones more readily available) and of combining substances into systems improving the properties of food products much more effectively than with individual component stabilizers.

CONCLUSIONS

1. Using suitable methods it is possible to compare functional properties of preparations belonging to various groups, both among vegetable hydrocolloids and among hydrocolloids and emulsifiers.

2. There is considerable differentiation of physico-chemical properties among the studied hydrocolloid groups, and among hydrocolloids and emulsifiers. This creates possibilities for mutual substitution of substances and for combining them into systems with specific functional properties.

3. All the investigated starches lack emulsifying capacities and they stabilize solutions by increasing their viscosity through pasting. Polish modified (phosphate) starches display poor functional properties. Their thickening capability is low, similar to that of natural starches, and their solubility in cold water (8-49⁰/o) is relatively poor, considering the type of starch they represent. They may be classified as the so called swelling starches requiring additional pasting by heating, and are not recommended as thickeners in instant desserts.

4. Emulsifiers are prominent among the studied stabilizing substances in view of their high foam formation and fat emulsification capabilities. However, frimulsion-type hydrocolloids are similarly effective emulsifying and emulsion stabilizing agents, sometimes even superior to emulsifiers.

5. Frimulsions exhibit the highest water adsorption among the investigated substances as well as high viscosity already at 1⁰/o concentration in solution. They are also highly effective emulsifying and emulsion stabilizing agents, equalling or even surpassing emulsifiers in these respects. This is evidence of their fairly diverse effect, both thickening and emulsifying.

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Manuscript received: April, 1986

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PORÓWNANIE WŁAŚCIWOŚCI FUNKCJONALNYCH WYBRANYCH HYDROKOLOIDÓW PRODUKCJI ROŚLINNEJ I EMULGATORÓW

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Streszczenie

Przeprowadzono ocenę porównawczą właściwości fizykochemicznych wybranych hydrokolooidów i emulgatorów produkcji krajowej i zagranicznej. Przebadano następujące grupy substancji stabilizujących: hydrokolooidy naturalne, skrobie naturalne i modyfikowane oraz emulgatory naturalne i syntetyczne.

Spośród substancji stabilizujących emulgatory wyróżniają się wysoką zdolnością pianotwórczą oraz wysoką zdolnością emulgowania tłuszczu, przy czym hydrokolooidy typu frimulsionów mają zbliżoną, a niekiedy nawet wyższą wydajność emulgowania i zdolność stabilizacji emulsji. Frimulsiony wyróżniają się bardzo wysoką, najwyższą spośród badanych substancji adsorpcją wody oraz wysoką lepkością nawet przy 1% stężeniach; świadczy to o ich wszechstronnym działaniu zarówno zagęszczającym, jak i emulgującym.

Wszystkie badane skrobie nie mają właściwości emulgujących, a stabilizują roztwory przez wzrost lepkości po ich skleikowaniu. Krajowe skrobie modyfikowane mają niską zdolność zagęszczania zbliżoną do skrobi naturalnych oraz niską zdolność rozpuszczania w wodzie na zimno. Można zaliczyć je do tzw. skrobi pęczniących wymagających dodatkowego skleikowania przez ogrzanie.