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ASSESSMENT OF THE POSSIBILITY OF USING AQUAFABA IN THE PRODUCTION OF VEGETABLE EMULSIONS®

Ocena możliwości zastosowania aquafaby w produkcji emulsji roślinnych®

Key words: aquafaba, chickpea; emulsifier, emulsion, mayonnaise.

Canning or boiling pulse seeds in water produces a by-product solution called aquafaba, is generally discarded as waste. However, this valuable resource contains high quantities of proteins with good functional properties. The paperarticle presents the assessment of the usefulness of aquafaba as a stabilizer in the production of vegetable emulsions with different fat content. The conducted research has shown that aquafaba can be successfully used for the production of vegetable emulsions (including mayonnaise) with a fat content of less than 75% and healthier alternatives compared to those available on the market.

Słowa kluczowe: aquafaba, ciecierzyca, emulgulator, emulsja, majonez.

Gotowanie nasion strączkowych w wodzie lub ich puszkowanie powoduje powstanie roztworu produktu ubocznego o nazwie aquafaba, który jest zwykle usuwany jako odpad. Ten wartościowy zasób zawiera jednak znaczne ilości białek o dobrych właściwościach funkcjonalnych. W artykule przedstawiono ocenę przydatności aquafaby jako stabilizatora w produkcji emulsji roślinnych o różnej zawartości tłuszczu. Przeprowadzone badania dowiodły, że aquafaba może być z powodzeniem stosowana do produkcji emulsji roślinnych (w tym majonezu) o zawartości tłuszczu poniżej 75% oraz zdrowszych alternatyw w porównaniu do dostępnych na rynku.

INTRODUCTION

Proteins derived from pulse seeds in terms of their ability to bind water, solubility, and other physicochemical properties, they can be suitable substitutes for proteins of animal origin [1]. The use of vegetable proteins, for example soybeans, to stabilize the emulsion, has been widely spread [15, 22]. Vegetable proteins are used as substitutes in vegan diets, comparing their properties with a typical source of protein – chicken eggs [6]. Legumes are most often used in production; soybeans, chickpeas, broad beans and various kinds of beans [9].

Aquafaba is a viscous liquid obtained after boiling chickpeas or other pulse seeds in water, which is a cooking leachate. Boiling the seeds in water causes some of the valuable ingredients to migrate into the liquid (aquafaba) [17]. Aquafaba consists of water (92–95%) and dry matter (5–8%), which includes carbohydrates, low molecular weight proteins (0.95–1.5% w/v, ≤ 24 kDa), saponins [8, 19]. The fluid is low-calorie, gluten-free and does not contain cholesterol. The protein content of canned aquafaba is about 13 g/100 g, this level of this ingredient allows to achieve stable emulsions [1]. The electrophoresis and analysis of aquafaba proteins indicate the predominant content of particles with a molecular weight of ≤24 kDa in the composition of this product. According to many authors, these are mainly albumin, which has exceptional foaming properties [14, 18]. Moreover, the presence of compounds such as saponins and amphiphilic glycosides acting as surfactants has the ability to emulsify [3]. The use of aquafaba in food products expands the market for food of plant origin, increases the demand for pulse seeds, and reduces the amount of wastewater generated in some bean production processes [8].

The aim of the research was to assess the possibility of using aquafaba as a stabilizer in the production of vegetable emulsions with different fat content.

MATERIALS AND METHODS

The aquafaba material used in this study originated from canned chickpeas. The canned chickpeas and rapeseed oil were purchased from a local supermarket (Groszek, Poland).

Emulsion preparation

Oil-in-water emulsions (O/W) were prepared by mixing aquafaba and rapeseed oil resulting in an oil part of 25, 33, 50, 66 and 75%. Aquafaba and oil sample was mixed by an Ultra Turrax T25 (IKA Werke GmbH & Co. KG, Germany) for 4 min at 15000 rpm.

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Physical properties of emulsion

Droplet size distribution of emulsion samples was measured as a function of time (0, 1, 3, 7, and 21 days) using a laser diffraction particle analyzer Cilas 1190 (Cilas, France). Drops of samples were added to the sample dispersion unit (containing water) until the obscuration index reached approximately 10%, and the average droplet size was reported in terms of volume mean diameter d_{50} [5].

The emulsion density was determined using a Densito 30PX densimeter (Mettler Toledo, USA).

The emulsion conductivity was determined using the Elmetron multifunction meter CX-505 with an Elmetron EC-201t electrode (Elmetron, Poland).

The colour characteristics were assessed using a CR-5 colorimeter (Konica Minolta, Japan), set on the CIELAB coordinates. Before measurement, the device was calibrated with a black and white calibration plate. Emulsion colour, represented by lightness (L*), redness/greenness (±a*), and yellowness/blueness (±b*), was determined after preparation.

Emulsion stability measurements were performed during storage for 0, 1, 3 and 7 days at 4°C, using Turbiscan Lab® Expert (Formulaction SA, France), which collected data from the entire height of the vial every 40 µm [5]. Round flat-bottomed vials were filled with the test emulsion (20 ml) to of ¾ their height. The Turbiscan Stability Index (TSI) was determined based on the Turbiscan Soft Lab software.

Statistical analysis

Experiments were conducted in triplicate and the data were presented as mean ± standard deviation (SD). The statistical analysis was performed by the statistical software, Statistica version 13.1 (StatSoft, Poland). Analysis of variance (ANOVA) and Tukey's post hoc statistical tests were used to evaluate significant differences in emulsion physicochemical properties. Statistical significance was accepted at $p < 0.05$.

RESULTS AND DISCUSSION

Physical properties of the emulsions obtained on the basis of aquafaba are presented in Table 1. The size of the dispersed phase particles affects the properties of emulsion systems present in food, including the appearance, structure, and taste. For the emulsion in which the ratio of aquafaba to oil was 3:1 (75% oil content), a stable obscurance of 10% was not obtained, which made it impossible to determine the droplets size. The emulsion with the oil content of 33% was characterized by the largest droplet size – 15.3 µm. The degree of dispersion and their coalescence in the emulsion formation process change depending on the fat content. It is well known that emulsions with droplets of small diameter tend to have a higher stability compared to emulsions of larger droplet diameter [11]. Moreover, it was observed that with the increase in the ratio of the dispersed phase, the size of the oil droplets decreased (Table 1). Thanonkaew et al. [20] found that o/w emulsions based on cold pressed rice bran oil are characterized by low oil droplet size values, and the degree of droplet breakdown and flocculation in the emulsion process change depending on the fat content.

As the proportion of oil in the emulsion increased, its density also decreased, which is logical as rapeseed oil has a lower density than water or aquafaba (Table 1). The density of the aquafaba from which the tested emulsion systems were prepared was 1050.1 kg/m^3. From the literature, the density of aquafaba ranges from 1009 to 1180 kg/m^3 [12, 18].

The tested emulsions showed a pH of 6.2, regardless of the ratio of aquafaba to oil, which indicates that the emulsion components were characterized by a similar pH value (Table 1). The slightly acidic pH of the emulsions obtained differed from the values obtained by other authors due to the lack of acidifying agents in the recipe [2, 16]. The participation of aquafaba in the emulsion had a significant impact on its conductivity. The higher content of aquafaba, the higher the conductivity of the emulsion, which can be related to the presence of ions passing into the leachate during the cooking process of chickpeas. Chickpea effluent mainly contains potassium and phosphorus [3, 22].

Along with the increase in the amount of the oil phase in the emulsion, its brightness (L*) increased, and the participation of green (-a*) and yellow (+b*) colours was also observed (Table 1). When comparing the colour parameters of the emulsion with the highest participation of the oil phase (75%) to the aquafaba-based mayonnaises obtained by Lafarga et al. [9]

Table 1. Physical properties of aquafaba-based emulsions and different fat content

Tabela 1. Właściwości fizyczne emulsji na bazie aquafaby o różnej zawartości tłuszczu

	Emulsion – fat content:				
	25%	33%	50%	66%	75%
Droplet size (µm)	11.2 ± 0.5^c	15.1 ± 0.1^d	10.5 ± 0.3^b	6.5 ± 0.1^a	-
Density (kg/m^3)	1002.1 ± 0.5^d	991.1 ± 1.5^c	948.3 ± 1.5^b	938.4 ± 0.3^a	936.2 ± 0.6^a
pH	6.1 ± 0.0^a	6.2 ± 0.0^a	6.2 ± 0.0^a	6.2 ± 0.0^a	6.2 ± 0.0^a
Conductivity (mS/cm)	9.3 ± 0.0^e	7.8 ± 0.0^d	4.9 ± 0.0^c	2.7 ± 0.0^b	1.9 ± 0.0^a
L*	70.3 ± 0.0^a	70.1 ± 0.0^a	71.0 ± 0.1^b	71.6 ± 0.2c	71.5 ± 0.4^c
a*	-0.8 ± 0.0^d	-1.4 ± 0.1^c	-1.7 ± 0.0^b	-2.4 ± 0.0^a	-2.5 ± 0.1^a
b*	22.9 ± 0.0^a	23.2 ± 0.1^b	23.4 ± 0.1^c	23.6 ± 0.0^d	24.6 ± 0.1^e

Source: Own study

Źródło: Opracowanie własne

and He et al. [7], it was noticed that the analyzed emulsion was characterized by lower brightness and a higher participation of colour yellow. Which indicates not only the differences in the composition of the emulsion (the proportion of aquafaba to oil), but also the significant impact on the colour of the emulsion by the variety of chickpeas and its processing, including the colour of aquafaba. The composition of aquafaba depends on: the conditions of extraction (soaking the seeds before cooking, the ratio of seeds to water, temperature, pH, time and pressure during extraction), the variety of chickpeas and the composition of the seeds and their structure [8]. Moreover, the brightness of the emulsion is influenced by the degree of fragmentation of the dispersed phase. Previous research has shown that the colour of the emulsion can change from gray to an increasingly lighter white colour with decreasing droplet size, possibly due to an increase in light scattering [13].

For each emulsion, the presence of at least two fractions of the dispersed phase, different in terms of droplet size, was observed (Fig. 1). Which is especially important in products with increased fat content. Smaller oil droplets, in the process of producing the emulsion, were packed between drops with larger diameters, creating a spatial lattice structure [10]. Probably the formation of a spatial grid and the optimal size of the fatty globules guarantee good stability of the emulsion [4].

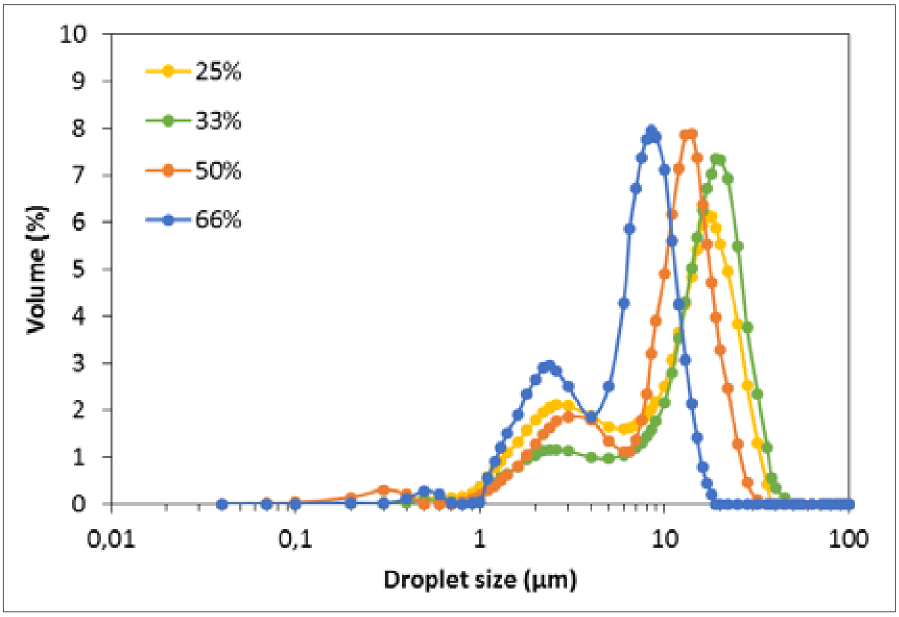

Fig. 1. Droplet size distribution in emulsions based on aquafaba and different fat content.

Rys. 1. Rozkład wielkości kropli w emulsjach na bazie aquafaby i różnej zawartości tłuszczu.

Source: Own study

Źródło: Opracowanie własne

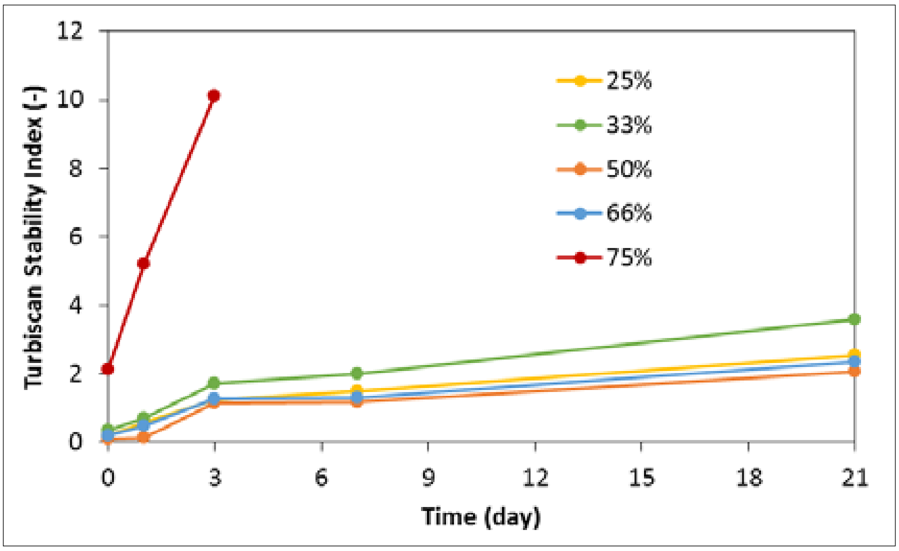

Fig. 2. Turbiscan Stability Index in emulsions based on aquafaba and different fat content.

Rys. 2. Wskaźnik stabilności TSI emulsji na bazie aquafaby i różnej zawartości tłuszczu.

Source: Own study

Źródło: Opracowanie własne

The stability of the dispersed system is one of the most important properties of an emulsion. In the conducted research, the Turbiscan Stability Index (TSI) was determined. The method is based on measuring the intensity of the light backscattered every 20 µm along the height of the sample. TSI is calculated by summing the back light scattering in successive measurements as a function of the sample height. By comparing TSI values, it was possible to determine the stability of various emulsion systems (Fig. 2). The higher the values of the TSI, the less stable the emulsion. Emulsions in which the participation of oil did not exceed 66% had a TSI below 4, which indicates good physical stability of the analyzed systems. Moreover, more stable emulsions were obtained when the size of the oil droplets did not exceed 11.2 µm. On the other hand, for the emulsion with the highest oil content at the level of 75%, the TSI value of 4 was exceeded after just one day of storage, which indicates its instability. Flocculation/coalescence is the main problem for the stability of high fat emulsions, which is the result of the convergence of oil droplets. Applying high-pressure homogenization could help to obtain an aquafaba-based emulsion with smaller droplet sizes and more stability during storage [7]. The most effective way to reduce coalescence is to generate strong repulsive forces between the droplets [15]. In the studies shown by He et al. [7], the stability of mayonnaise (pH = 4, 80% fat) based on aquafaba during storage was confirmed, which indicates that the pH of the emulsion may affect its stability. The results are agreed with the research of Tontul et al. [21] who showed that in the pH range 2-10, emulsions based on the chickpea protein isolate are characterized by different stability.

SUMMARY

The use of aquafaba in food production meets global efforts to minimize by-products. Chickpea seeds have many minerals that pass into the aquafaba. Aquafaba can be successfully used to produce vegetable emulsions (including mayonnaises) with a fat content below 75% and healthier alternatives compared to those available on the market.

The presence of at least two fractions of the dispersed phase, different in terms of the size of the oil droplets, was observed in the emulsions. This indicates that the smaller oil droplets, in the emulsion production process, were packed between the larger droplets, creatine a spatiae grid structurh thad guarantees good stability to the analyzed systems.

PODSUMOWANIE

Zastosowanie aquafaby w produkcji żywności spełnia globalne wysiłki na rzecz minimalizacji produktów ubocznych. Nasiona ciecierzycy posiadają wiele składników mineralnych, które przenikają do aquafaby. Aquafaba, może być z powodzeniem stosowana do wytworzenia emulsji roślinnych (w tym majonezów) o zawartości tłuszczu poniżej 75% oraz zdrowszych alternatyw w porównaniu do dostępnych na rynku.

W emulsjach obserwowano występowanie co najmniej dwóch frakcji fazy zdyspergowanej zróżnicowanych pod względem wielkości kropel olejowych. Wskazuje to, że mniejsze kropelki oleju, w procesie wytwarzania emulsji, zostały upakowane pomiędzy kroplami o większych rozmiarach, tworząc strukturę siatki przestrzennej, która gwarantuje dobrą stabilność analizowanym układom.

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