Food Science and Engineering
http://ojs.wiserpub.com/index.php/FSE/

UNIVERSAL WISER PUBLISHER

Research Article

Development and Evaluation of High Protein Spread Based on Aquafaba

Atul Kumar, Dadasaheb Wadikar*, Santosh Pal, Dev Kumar Yadav, Anil Dutt Semwal

Grain Science & Technology Division, Defence Food Research Laboratory, Siddartha Nagar, Mysore, Karnataka, India
E-mail: ddwadikar@gmail.com

Received: 14 June 2023; **Revised:** 8 October 2023; **Accepted:** 13 October 2023

Abstract: A study was undertaken to optimize the process of the preparation of aquafaba powder mix and ingredient composition for preparation of pulse-based spread, using combinations of garbanzo bean flour, aquafaba powder and fat (olive oil and hydrogenated fat). The aquafaba powder, garbanzo bean flour, and spices were the solid phase while the olive oil, hydrogenated fat, tomato paste, and water were the liquid phase with lecithin as an emulsifier. The effect of the aquafaba powder and liquid phase on the textural properties of the spread was studied and further the developed spread was comparatively evaluated with the commercially available spread. Hardness and spreadability are important parameters for the overall acceptability of the spread and were found to be influenced by the type of fat and quantity of fat used to develop the spread.

***Keywords*:** spread, aquafaba, garbanzo bean, texture, hardness and spreadability

1. Introduction

The viscous liquid of cooked legumes or especially garbanzo bean is called aquafaba. It consists of carbohydrates, proteins, and soluble plant solid components which impart functional properties like thickening, emulsifying, foaming, and binding properties. It can mimic both egg white and milk proteins. The impartation of desirable characteristics and properties of spread are also depending upon the functionality and characteristic of garbanzo bean flour. Spread has become customarily a part of daily breakfast and the consumption of spread is increasing around the world [1]. The spread segment covers food products that are intended to spread over other food such as bread. Spreads typically have a semisolid or creamy texture and are available in wide range of flavors such as jam, marmalade and peanut butter. The spread market in India is expected to grow 6.87% annually from 2023 revenue of 2,171 million US$ [2]. Indian market also flooded with different type of spreads mostly dairy-based and some are nut-based, but pulse-based spread is uncommon. The rise in demand for spreads and related products can be ascribed to changing breakfast patterns and rising demand for convenience foods. Increasing lifestyle related diseases among the population has increased awareness for healthier eating and forced food industries to look for convenience, instant and healthier alternative or designer foods which cater constantly changing demand of the consumer. Pulse flour and protein are known for their health benefits and functional properties. Pulse based spreads can be healthy choice for protein seeking consumers. The pulse flour can be used to develop a potential non-dairy and reduced fat/calorie spreads; therefore, this research was aimed to develop, evaluate and stabilize a pulse-based spread.

DOI: https://doi.org/10.37256/fse.4220233226

2. Materials and methods

2.1 *Materials*

Extra virgin olive oil (Figaro, Italy), Hydrogenated fat, Brown sugar, Tomato paste, Black pepper, Onion powder, Garlic powder, Chilli powder, Desi Chickpea flour (roasted flour), and Garbanzo bean (kabuli chana) were procured from local city market. Lecithin and Malto-dextrin of commercial grade are procured from (M/s. Fine Organic Ind., Mumbai). The commercial spread samples viz. Fun foods sandwich spread cucumber & carrot (M/s. Dr. Oetker India Pvt. Ltd.) and Plain Sundrop Peanut Butter Creamy (M/s. Agro Tech Food Ltd.) were procured. The commercial samples (CS) are referred as CS-1 and CS-2.

2.2 *Processing/preparation methods*

2.2.1 *Pulse flour*

Ten kg of garbanzo beans were soaked in water containing 215 grams of sodium bicarbonate for 12 hours. The soaked garbanzo was pressure cooked at 115 °C for 2 hours and excess liquid was strained off after cooling. 7.5 kg of cooked garbanzo beans were dried using fluidized bed drier and roasted at 170 °C for 18-20 min with constant stirring in an open pan (conventional method). The remaining garbanzo bean was toasted (cook by exposure to radiant heat) with oil at 230 °C for 30-40 min. Both roasted and toasted samples were ground in a mill into flour and passed through British Standards Sieve (BSS) 60-mesh sieve and thus obtained flours were used for further processing.

2.2.2 *Aquafaba powder*

For the preparation of aquafaba powder, strained water from the cooked garbanzo bean was concentrated to 10% Total Soluble Solids (TSS) and mixed with maltodextrin and gum acacia powder to increase total soluble solids content to 14-18%. The concentrated slurry then strained through a muslin cloth. The strained solution was dispersed into spray dryer at an inlet temperature of 180 °C, the outlet temperature of 160 °C, and cooling temperature 50 °C. Spray gas flow rate 90 m^3/hr, feed pump flow rate 35 ml/min, product inlet temperature 40 °C and product TSS 14.4%.

2.2.3 *Preparation of spread*

Spreads were prepared after conducting the trial experiments where the ratio of dry phase and liquid phase were studied and efficiency of dry phase to withhold the liquid phase was measured. 50 gm of garbanzo bean flour and aquafaba powder mix (Dry phase) were able to hold 20 gm of liquid phase above which oozing out liquid phase (oil or fat) is visible. The fat content remains constant at 20 g in Table 1, in the form of oil and hydrogenated fat.

The spread composition consists of two phases: Dry phase consist of garbanzo bean flour, aquafaba powder, milk powder and spices. Dry phase material was pulverized by Retsch ZM-200 rotor mill and sifted through the 0.5 mm trapezoid size sieve. The liquid (oil) phase consisted of olive oil, hydrogenated fat, tomato paste made up the total formulation.

Malto-dextrin and lecithin were added to the liquid phase and stirred until completely dissolved.

The quantity of the olive oil and hydrogenated fat was varied in different ratios and its influence on textural profile was investigated. The liquid phase was added gradually into the dry phase and it was blended for 10 min at low speed with high shear mixing and packed in 100 g pouch and sous vide treated as per method [3] with slight modification.

The different combinations used in experiment are as follow: Four combinations of mixes were prepared by varying four-parameter garbanzo bean flour, aquafaba powder, hydrogenated fat and olive oil concentration (Table 1). The levels of Tomato pulp, Milk Powder, Spices, Maltodextrin and Lecithin were kept constant at 12.0%, 5%, 10%, 2.5% and 0.5%, respectively to maintain minimum variations in the experiment.

Table 1. Experimental combinations for spread

	Garbanzo Bean flour	Aquafaba powder	Olive oil	Hydrogenated fat
C-I	40	10	20	0
C-II	35	15	15	5
C-III	30	20	10	10
C-IV	25	25	5	15

2.3 *Analytical methods*

2.3.1 *Chemical analyses*

The proximate composition parameters such as Moisture content, Protein, Crude fat and Ash were determined using Association of Official Analytical Chemists (AOAC) methods [4] wherein for moisture estimation, 5 g sample was accurately weighed in aluminum dishes and heated in a hot air oven at 105 ± 2 °C for 1 hr and weighed after cooling in a desiccator. Protein was estimated by the kjeldahl method using Gerhardt nitrogen digestion(turbo-therm) and distillation (Vapodest) auto apparatus. Fat content was estimated by using Soxhlet apparatus while total ash content in the sample was using Muffle Furnace and silica crucibles.

Other various functional properties were studied by different methods described further. The swelling capacity was determined by the method described by Okaka & Potter [5]. 100 ml graduated cylinder was filled with the sample to 10 ml mark. The distilled water was added to give a total volume of 50 ml. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. The suspension was inverted again after 2 min and left to stand for a further 8 min. The volume occupied by the sample was taken after the 8th min.

The water absorption capacity (WAC) of the flours was determined [6] wherein, one gram of flour sample (garbanzo bean flour and aquafaba powder) was mixed with 10 ml distilled water in pre-weighed centrifuge tube. The suspension was stirred for 1 hr and centrifuged at 5,000 g for 40 minutes. Water absorption was expressed as percent water-bound per g of flour. The oil absorption capacity (OAC) was also determined by the method similar to the water absorption capacity of garbanzo bean flour, by replacing water with olive oil.

Water holding capacity (WHC) was determined using the method described by Sowbhagya et al. [7]. Sample (1 g) was accurately weighed into a graduated test tube and 30 ml of distilled water was added. The content was allowed to hydrate for 18 h at ambient temperature and then filtered through Whatman No.1 filter paper. The hydrated residue weight was recorded and it was dried at 105 ± 2 °C to get a constant weight. The results were expressed as ml of water held per 100 g of dry sample.

The Oil Holding Capacity (OHC) was determined by the method similar to the Water Holding capacity of garbanzo bean flour, with slight modification and by replacing water with olive oil. The dispersed suspension was stirred for 24 hr before to centrifugation at 5,000 g for 40 min. The supernatant was decanted and the samples were re-weighed.

The emulsion activity and emulsion stability of garbanzo bean flour and aquafaba powder were determined using the method described by Aguilera et al. [8]. To determine the emulsion activity of garbanzo bean flour and aquafaba powder, one gram of garbanzo bean flour and aquafaba powder was mixed with 25 ml of water and store at 20 °C for 30 min. Subsequently, 25 ml of olive oil was added and the mixture was emulsified by homogenization for 3 min. The emulsion was centrifuged at 2,000 × g for 5 min. The ratio of the height of the emulsion layer to the total height of the mixture was calculated as emulsion activity in percentage. The emulsion stability was estimated after heating the emulsion contained in the calibrated centrifuged tube at 80 °C for 30 min in a water-bath, cooling for 15 min under running tap water, and centrifuging at 2,000 × g for 15 min. The emulsion stability expressed as a percentage. It was calculated as the ratio of the height of the emulsified layer to the total height of the mixture.

The Foam capacity (FC) and Foam stability (FS) [8] of flour were determined wherein one g of garbanzo bean flour and aquafaba flour was added to 50 ml distilled water at 30 ± 2 °C in a graduated flask. The suspension was whipped using a homogenizer at 5,000 g for 5 min. Sample volumes were measured before and after whipping. The volume of

foam was recorded 4 hours after whipping to determine foam stability as per percent of initial foam volume.

2.3.2 *Instrumental texture profile analysis*

Samples of the spread (100 g) at temperature 25 °C were put into a cylindrical bloom jar (40 mm in diameter) with special attention to avoid bubble formation and kept at 5 °C and 25 °C. The texture profile analysis was carried out using TA-XT HD2 Texture Analyzer with a Texture Technology Corp (TTC) probe-P36 with bloom jar attachment (Stable Micro System, UK). Spread hardness, springiness, adhesiveness, cohesiveness, gumminess, resilience and chewiness were investigated. The accessories and parameters used for texture analysis using load cell of 5 kg. Test condition used for analysis of spread texture are similar as reported by Bonczar et al. [9] with slight modification-Pre-test speed of 1.0 mm/sec, test speed of 1.00 mm/sec, post-test speed 5.00 mm/sec, target mode-distance, distance 20.00 mm, strain 75.00%, time 10.00 sec, trigger type-auto force, trigger force-0.5 N, trigger distance-2.0 mm, tare mode-auto, advanced option -on, probe-P/36 with bloom jar (40 mm filled), start position-43 mm and temperature 5 °C and 25 °C. Similar texture study methods are reported [10].

Spreadability (Work of Shear) was measured [10] using TA-XT HD2 Texture Analyzer with a TTC Heavy Duty Platform/Spreadability Rig (HDP/SR) attachment (Stable micro system, UK). Samples were filled into female cone (90° angle) with special attention to avoid bubbles formation and identically as it were carried out for the texture analysis procedure: half of the female cones were taken for analysis at 20 °C and the other half was stored at 5 °C for overnight and the spreadability was analyzed immediately after this storage. During the analysis, samples were displaced to within 0.5 mm of the base of the female cone using a corresponding male cone (90° angle) attachment for the texture analyzer. Force expressed in Newtons was measured for the duration of the test, and spreadability was equated to the area under the curve. As more easily spreading samples required smaller forces to be displaced from the female cone, smaller values reflected easier spreadability. The accessories used for all measurement was cone-shaped HDP/SR. Each sample was directly tested in the original container, without mixing, at given test condition of pre-test speed 1.00 mm/sec, test speed 3.00 mm/sec, post-test speed 10.00 mm/sec, target mode-10.00 mm/sec, target mode-distance, distance-21.00 mm, strain 10%, trigger type-button, trigger force 5.0 g, trigger distance 2.0 mm, break mode-off, break sensitivity 10.0 g, sample size-10 gram and HDP/SR probe. The procedure is recommended by textural analyzer software.

2.4 *Storage analysis*

Storage studies were conducted for the product at room temperature and the parameters studied for periodic analysis were Peroxide Valve (PV), Free Fatty Acids (FFA), Thio-Barbituric Acid (TBA) value and Browning index. These were measured using standard AOAC methods [11]. Peroxide values give the initial indication of rancidity in fat and oil samples and was expressed as meqO_2/Kg fat. The FFA analysis gives the amount of free fatty acid present in the food sample and measures the hydrolytic rancidity in the food sample. The FFA content expressed as % oleic acid. TBA value is the measure of oxidative rancidity in oils, fats, and food products.

The sensory profile was periodically evaluated as overall acceptability (OAA) of the product on 9-point hedonic scale for its quality attributes like color, aroma, texture, and taste. Sensory evaluation analyses and measures the human response to the composition of food and acceptability by the consumer. Periodic analysis of Texture profile was done using TA-XT HD2 Texture Analyzer.

3. Results and discussion

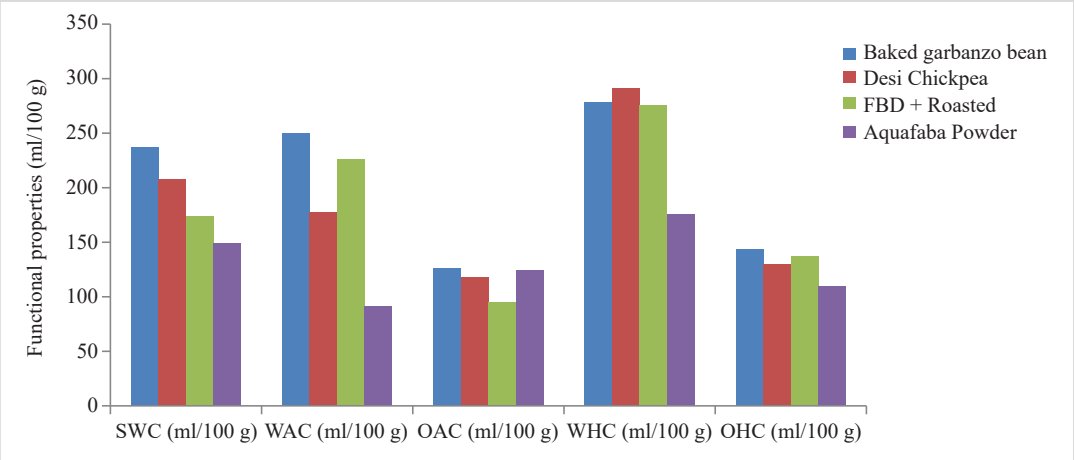
Various raw materials used for preparation of spreads were of studied for their physicochemical properties and the effect of pre-processing on them. Proximate composition of processed garbanzo bean flour and spray dried aquafaba powder are shown in Table 2. The moisture, protein, fat, ash and carbohydrate content of processed garbanzo bean flour lies in the range of 4.97%-5.49%, 22.65%-23.11%, 8.36%-11.12%, 3.61%-5.10% and 55.16%-59.54%. It was observed that, the proximate analyses vary significantly among garbanzo bean flour depending upon the method of processing flour and aquafaba powder. The protein and carbohydrate content of processed garbanzo beans were similar to the value reported by Kaur and Singh [12], however the fat and ash content are slightly higher than the reported values. Analysis

of desi chickpea flour showed it consist of 22.95% protein, 5.92% fat, and 64.12% carbohydrate while that of aquafaba powder shows it consist of 2.86% protein, 7.59% fat, and 84.35% carbohydrate. This indicates that aquafaba powder mainly serves as the source of carbohydrate and fat.

Table 2. Proximate composition of garbanzo bean and desi-chick pea flour

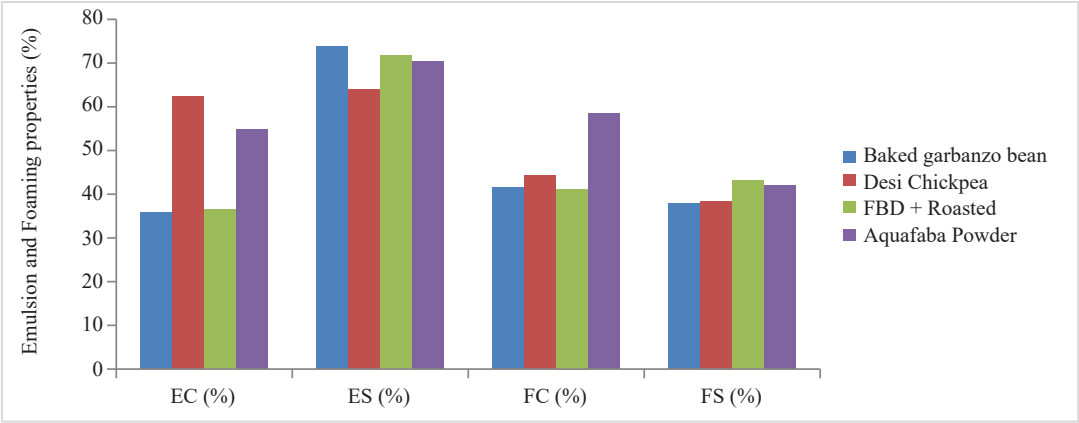
Raw materials (Flour)	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)
Garbanzo bean flour (baked)	4.97 ± 0.30^{b}	22.65 ± 0.07^{b}	11.12 ± 0.07^{d}	5.10 ± 0.01^{d}	55.16 ± 0.44^{a}
Desi chickpea	4.72 ± 0.14^{b}	22.95 ± 0.21^{b}	5.92 ± 0.13^{a}	2.28 ± 0.01^{a}	64.12 ± 0.05^{c}
Garbanzo bean flour FBD + (Roasted)	5.49 ± 0.13^{c}	23.11 ± 0.99^{b}	8.36 ± 0.01^{c}	3.61 ± 0.00^{b}	59.54 ± 0.86^{b}
Aquafaba powder	0.65 ± 0.05^{a}	2.86 ± 0.03^{a}	7.59 ± 0.03^{b}	4.62 ± 0.01^{c}	84.35 ± 0.02^{d}

Values with different superscript in columns differ significantly ($p \leq 0.05$); Values are mean ± SD



SWC-Swelling Capacity, WAC-Water Absorption Capacity, OAC-Oil Absorption Capacity, WHC-Water Holding Capacity, OHC-Oil Holding Capacity

Figure 1. Functional properties of processed flours (roasted, fluidized bed dryer + baked)



EC-Emulsion Capacity, ES-Emulsion Stability, FC-Foaming capacity and FS-Foaming stability

Figure 2. Emulsion and foaming properties of selected flour

3.1 *Functional properties of pulse flour*

Water and Oil absorption capacity represents the ability of the flour to associate with water or oil, while the water and oil holding capacity represent the ability of a flour system to physically hold water or oil against gravity [13]. The functional properties of processed garbanzo bean flour, desi-chickpea flour, and aquafaba powder are shown in Figure 1. The WAC and OAC of garbanzo bean flours ranged from 225.57-250.23 ml/100 g and 95.18-126.35 ml/100 g. While the WAC and OAC of desi-chickpea flour and aquafaba powder were found to be 177.03 ml/100 g and 91.55 ml/100 g and 117.58 ml/100 g and 124.23 ml/100 g, respectively. These WAC and OAC observations are higher than the value reported by Kaur and Singh [12]. The higher value of WAC may be due to ultra-structural changes that occur during processing. The WHC and OHC of garbanzo bean flour, desi chickpea flour, and aquafaba powder were found to be 275.67-278.37 ml/100 g, 291.27 ml/100 g, 175.67 ml/100 g and 137.45-143.21 ml/100 g, 129.83 ml/100 g and 109.24 ml/100 g. These values are similar to the values reported by Xu et al. [14] with slight variation. Swelling capacity indicates how much the food matrix swells as water is absorbed [15]. The swelling capacity of garbanzo bean flour, desi chickpea flour, and aquafaba powder found to be 173.43-236.76 ml/100 g, 207.79 ml/100 g, and 149.02 ml/100 g. The emulsion and foaming properties of flour (Figure 2) reveals that significant differences were found among garbanzo bean flour, desi-chickpea flour, and aquafaba powder with respect emulsion activity, emulsion stability, foam capacity, and foam stability. Emulsion activity of garbanzo bean flour, desi-chickpea flour, and aquafaba powder was found to be 35.83-36.47%, 62.27%, and 54.90%. Emulsion stability of three flours found to be 71.65-73.82%, 63.94%, 70.30%. Foam capacity and foam stability of garbanzo bean flour, desi-chickpea flour, and aquafaba powder were found to be 41.20-41.57%, 44.32%, 58.55% and 37.90-43.19%, 38.45%, 42.01%. The values reported were higher than the value reported by Xu et al. [14]. This variation in the above values may be due to variety and environmental conditions. Based on functional properties of garbanzo bean and aquafaba powder to bind oil and water in its matrix and formation of emulsion stability without weeping out of liquid phase from the spread matrix. Based on above functional properties combination of garbanzo flour and aquafaba powder is used to develop spread. The protein and polysaccharide associative interaction causes electrostatic complexes that improve textural properties, emulsifying ability and coalescence stability.

3.2 *Textural properties of pulse-based spread*

Spreadability is the most essential feature perceived by the consumer concerning butter, margarine and the acceptability of a spread [16]. Three factors that affect the hardness and spreadability of the spread are percentage of fat, variety of fat, and temperature [10]. The four spread combinations developed were compared with the commercial sample for their textural properties at two different temperatures 5 °C and 20 °C. There was a significant difference ($P \leq 0.05$) between the developed spread and commercial spread with respect to firmness and work of shear at two temperatures. It was found that both firmness and work of shear increases with increase in fat percentage, and a decrease in temperature. Firmness and work of shear of the developed spreads (C-I to C-IV) and commercial spreads (CS-1, 2) are shown in Table 3. Firmness of the developed spread combination lied in the range of 0.86 ± 0.01 to 1.59 ± 0.09 at 5 °C. There were significant differences among commercial spread samples with respect to firmness. Firmness of the commercial samples was found to be in the wide range from 0.73 ± 0.00 to 1.86 ± 0.00. There was no significant difference among the combinations C-II, C-III and C-IV except in C-1 where the firmness of the spread was 0.8636 ± 0.00. This may be due to the composition of fat. Changes in the lipid composition lead changes in molecular packing of crystals causes transformation of polymorphism and crystalline domain size [17]. Saturated fatty acids interacted with stabilizer crystals to form firmer structure [18]. Work of shear for the developed combination of spread and commercial spread found to be in the range of 0.66 ± 0.01 to 1.59 ± 0.08 and 0.33 ± 0.00 to 1.86 ± 0.12, respectively. Significant reduction seen in the firmness and work of shear of developed spread sample and commercial spread sample with increase in temperature (at 20 °C). At 20 °C firmness of the developed spread sample and commercial spread sample found to be in the range of 0.29 ± 0.02 to 0.89 ± 0.05 and 0.30 ± 0.00 to 1.67 ± 0.08 Kg, whereas Work of shear found to be in the range of 0.24 ± 0.01 to 0.61 ± 0.03 and 0.17 ± 0.00 to 1.10 ± 0.08 kg. sec., respectively.

Textural properties of pulse-based spread were carried out by the TA-texture analyzer. Textural properties influencing the customer acceptance (Hardness and Spreadability) were studied at two different temperatures. Textural properties of pulse-based spread can be comparable to the commercially available sample and it remains softer at lower

temperature. Garbanzo bean flour and aquafaba powder showed significant effect on textural properties. The Hardness of the spread increased significantly with decrease in temperature. The texture profile analysis of the four combination spread mixes and commercial samples at 5 °C and 20 °C are shown in Table 4. The hardness of the two commercial sample increased from 0.97 ± 0.06 to 31.1287 ± 0.33 N and 18.14 ± 0.50 to 116.3231 ± 0.43 with a decrease in temperature. Similar trends are shown by all the four combinations of developed spread sample where hardness of the developed spread sample increased from 1.16 ± 0.01 to 69.30 ± 2.26, 2.41 ± 0.18 to 98.38 ± 0.79, 3.74 ± 0.095 to 129.28 ± 0.77 and 8.72 ± 0.22 to 113.38 ± 1.64, respectively. The CS-2 (Peanut butter) was the hardest among the compare samples this may be due to the higher concentration of stabilizers 1.6 to 2.0% [19, 20]. Hardness in four developed spreads increased as the percentage of saturated fat increases, and the amount of garbanzo bean flour increases. The hardness of the developed spread was lower than the CS-2, due to the low level of stabilizer and higher amount of unsaturated fat. The developed spreads were harder than CS-1, due to lesser content of oil and comparatively higher saturated fat. The Hardness value reported for commercial samples were similar to the value of hardness reported by Glibowski et al. [10] and slightly higher than reported by Dubost et al. [21]. The adhesiveness of commercial and developed spread sample increases when it is stored at 5 °C. The adhesiveness increases with incorporation of garbanzo bean flour, increase in fat content and saturated fat percentage [22]. There were no significant changes in springiness of the commercial and developed spread sample. Springiness of the commercial and developed spread sample lied in the range of 0.90 ± 0.00 to 0.98 ± 0.01 and 0.92 ± 0.05 to 0.96 ± 0.02 at 20 °C, at 5 °C springiness of commercial and developed spread sample lied in the range of 0.9743 ± 0.023 to 1.1243 ± 0.05 and 0.9666 ± 0.00 to 0.9976 ± 0.02 respectively. Cohesiveness of commercialized spread at two experimental temperature lied in the range of 0.7679 ± 0.024 to 0.8743 ± 0.00 at 5 °C and 0.84 ± 0.03 to 0.86 ± 0.03 at 20 °C. Developed spread cohesiveness found to be in the range of 0.53 ± 0.01 to 0.79 ± 0.05 at 5 °C and 0.67 ± 0.01 to 0.86 ± 0.00 at 20 °C respectively. Cohesiveness decreases in spread on incorporation of flour samples [23]. Gumminess and chewiness of commercial samples at 5 °C found to be in the range of 23.60 ± 0.29 to 101.70 ± 1.23 and 27.07 ± 0.85 to 99.09 ± 3.15. Gumminess and chewiness of developed spread sample combination at 5 °C found to be 55.22 ± 4.27 to 71.48 ± 2.25 and 55.13 ± 5.07 to 71.10 ± 2.13.

Table 3. Firmness and work of shear of spread sample: developed Combination (C) and Commercial Sample (CS)

Sample	Spreadability at 5 °C		Spreadability at 20 °C	
	Firmness (Kg)	Work of Shear (kg.sec)	Firmness (Kg)	Work of Shear (kg.sec)
C-I	0.86 ± 0.01^{b}	0.66 ± 0.01^{b}	0.29 ± 0.02^{a}	0.24 ± 0.01^{a}
C-II	1.49 ± 0.03^{c}	0.94 ± 0.07^{c}	0.79 ± 0.04^{b}	0.73 ± 0.02^{b}
C-III	1.47 ± 0.01^{c}	0.95 ± 0.00^{c}	0.94 ± 0.00^{c}	0.85 ± 0.02^{b}
C-IV	1.59 ± 0.09^{c}	1.59 ± 0.08^{d}	0.89 ± 0.05^{c}	0.61 ± 0.03^{b}
CS-1	0.73 ± 0.00^{a}	0.33 ± 0.00^{a}	0.30 ± 0.00^{a}	0.17 ± 0.00a
CS-2	1.86 ± 0.01^{d}	1.86 ± 0.12^{e}	1.67 ± 0.08^{d}	1.10 ± 0.08^{c}

Values with different superscript in columns differ significantly ($p \leq 0.05$); Values are mean ± SD

3.3 *Sensory evaluation of pulse-based spread*

Sensory evaluation of pulse-based spread shown in Table 5. Composition of dried spread mix and including aquafaba powder and liquid phase containing olive oil, hydrogenated oil and lecithin do not affect significantly sensory parameter like color, aroma, taste of pulse spread, but it affected textural properties of the pulse spread lead to lower OAA of pulse-based spread. The sensory score on the basis of textural value of spread lies in the range of 7.25-7.81. Where C-III show the highest OAA. When compared with the commercial samples (CS-1 & CS-2), the sensory score was better in case of CS-1 and matched with that of C-III showing no significant difference.

Table 4. Textural properties of Spread sample: developed Combination (C) and Commercial Sample (CS)

Textural properties at 5 °C						
Sample	Hardness (N)	Adhesiveness (g. sec)	Springiness	Cohesiveness	Gumminess	Chewiness
C-I	69.30 ± 2.26^{b}	-788.63 ± 8.70^{e}	0.99 ± 0.02^{a}	0.79 ± 0.05^{d}	55.22 ± 4.27^{b}	55.13 ± 5.07^{b}
C-II	98.83 ± 0.79^{c}	-1,363.32 ± 19.58^{d}	0.96 ± 0.00^{a}	0.72 ± 0.01^{c}	71.79 ± 1.85^{c}	69.39 ± 1.26^{c}
C-III	129.28 ± 0.77^{e}	-1,692.91 ± 13.52^{b}	0.99 ± 0.00^{a}	0.5323 ± 0.01^{a}	68.77 ± 1.73^{c}	68.34 ± 1.58^{c}
C-IV	113.38 ± 1.64^{d}	-2,657.69 ± 112.76^{a}	0.99 ± 0.00^{a}	0.63 ± 0.01^{b}	71.48 ± 2.25^{c}	71.10 ± 2.13^{c}
CS-1	31.12 ± 0.33^{a}	-523.56 ± 4.95^{f}	1.12 ± 0.05^{a}	0.76 ± 0.024^{cd}	23.60 ± 0.29^{a}	27.07 ± 0.85^{a}
CS-2	116.32 ± 0.50^{d}	-1,552.59 ± 6.09^{c}	0.97 ± 0.023^{a}	0.8743 ± 0.00^{e}	101.70 ± 1.23^{d}	99.09 ± 3.15^{d}
Textural properties at 20 °C						
Variable	Hardness (N)	Adhesiveness (g.sec)	Springiness	Cohesiveness	Gumminess	Chewiness
C-I	1.16 ± 0.01^{a}	-343.47 ± 6.28^{e}	0.96 ± 0.02	0.86 ± 0.00^{b}	0.99 ± 0.00^{a}	0.95 ± 0.02a
C-II	2.41 ± 0.18^{b}	-975.99 ± 35.88^{d}	0.93 ± 0.04	0.81 ± 0.06^{b}	1.92 ± 0.01^{b}	1.78 ± 0.11b
C-III	3.74 ± 0.09^{c}	-1,861.49 ± 163.80^{c}	0.94 ± 0.06	0.72 ± 0.04^{a}	2.76 ± 0.01^{c}	2.60 ± 0.17c
C-IV	8.72 ± 0.22^{d}	-4,163.93 ± 307.3^{a}	0.92 ± 0.05	0.67 ± 0.01^{a}	5.82 ± 0.25^{d}	5.44 ± 0.52d
CS-1	0.97 ± 0.06^{a}	-573.98 ± 47.80^{e}	0.90 ± 0.00	0.86 ± 0.03^{b}	0.82 ± 0.02^{a}	0.74 ± 0.01a
CS-2	18.14 ± 0.5^{e}	-3,019.73 ± 228.79^{b}	0.98 ± 0.01	0.84 ± 0.03^{b}	14.96 ± 0.13^{e}	14.59 ± 0.28e

Values with different superscript in columns differ significantly ($p \leq 0.05$); Values are mean ± SD

Table 5. Sensory Studies of Spread sample: developed Combination (C) and Commercial Sample (CS)

Sample	Color	Odour	Taste	Texture	OAA*
C-I	7.54 ± 0.47^{a}	7.64 ± 0.46^{a}	7.51 ± 0.71^{a}	7.25 ± 0.58^{a}	7.34 ± 0.69^{a}
C-II	7.47 ± 0.50^{a}	7.56 ± 0.50^{b}	7.67 ± 0.49^{a}	7.28 ± 0.65^{a}	7.38 ± 0.48^{a}
C-III	7.67 ± 0.71^{a}	7.87 ± 0.41^{a}	7.85 ± 0.40^{a}	7.81 ± 0.56^{c}	7.87 ± 0.62^{c}
C-IV	7.45 ± 0.68^{a}	7.68 ± 0.56^{a}	7.65 ± 0.55^{a}	7.59 ± 0.49^{ab}	7.62 ± 0.50^{b}
CS-1	7.65 ± 0.82^{a}	7.84 ± 0.50^{a}	7.85 ± 0.55^{a}	7.70 ± 0.19^{c}	7.91 ± 0.50^{c}
CS-2	7.55 ± 0.82^{a}	7.54 ± 0.54^{a}	7.60 ± 0.55^{a}	7.62 ± 0.20^{c}	7.61 ± 0.50^{b}

Values with different superscript in columns differ significantly ($p \leq 0.05$); Values are mean ± SD
*OAA: Over All Acceptability

3.4 *Evaluation of the final spread*

Among the four spreads developed, the C-III was found most acceptable and the same was evaluated for its proximate composition and shelf life. The proximate composition of C-III pulse-based spread contains 8.94% moisture, 13.58% protein, 15.56% fat, 2.94% ash, and 58.98% carbohydrate. The reconstituted (with water) pulse-based spread mix consist of 33.61% moisture, 9.25% protein, 12.55% fat, 1.80% ash, and 42.78% carbohydrate.

The results of shelf-life evaluation study of reconstituted spread mix (Table 6) revealed that the developed spread remains stable for a period of 30 days. Peroxide value and free fatty acid increases from 1.52 ± 0.02 to 1.93 ± 0.05 meqO_2/Kg fat and 0.11 ± 0.02 to 0.18 ± 0.01% oleic acid. TBA value and browning index of the spread mix was found to be 0.049 ± 0.00 to 0.076 ± 0.00 and 0.24 ± 0.01 to 0.35 ± 0.02, respectively.

Table 6. Shelf-life study of developed spread

Parameter/duration	Initial	15th day	30th day
Moisture (%)	33.61 ± 0.16^{a}	33.56 ± 0.11^{a}	33.48 ± 0.09^{a}
PV (meqO_2/Kg fat)	1.52 ± 0.02^{a}	1.65 ± 0.04^{a}	1.93 ± 0.05^{b}
FFA (% Oleic acid)	0.11 ± 0.02^{a}	0.13 ± 0.00^{a}	0.18 ± 0.01^{b}
TBA (mg malonaldehyde/kg fat)	0.049 ± 0.00^{a}	0.058 ± 0.03^{b}	0.076 ± 0.02^{c}
Browning	0.24 ± 0.01^{a}	0.29 ± 0.01^{b}	0.35 ± 0.02^{c}
Over all acceptability score	7.87 ± 0.03^{c}	7.85 ± 0.05^{b}	7.80 ± 0.02^{a}

All values are mean ± SD; Values with different superscript in a row differ significantly ($p \leq 0.05$)

4. Conclusion

A pulse-based spread using combinations of garbanzo bean flour, aquafaba powder, olive oil and hydrogenated fat was developed. Combination of garbanzo bean flour and aquafaba powder may causes interaction between proteins and polysaccharides through covalent or electrostatic interaction and facilitating the stabilization of the system. Protein and polysaccharide complexes and interaction providing a product with low fat content but, comparable to commercial spread sample. Textural property of spread was most influenced by the aquafaba powder and liquid phase. The hardness and spreadability of the spread were dependent on the composition and quantity of fat used to develop the spread. The product developed was found comparable with commercially available spreads. The reconstituted spread has a shelf life of one month at ambient conditions. Further work can be explored on shelf stability of such products.

Acknowledgements

We would like to thank Dr. T. Anand, [Coordinator-MSc. DFRL, Mysore] and Dr. Saibal Banerjee [MSc-Coordinator, DIAT, Pune] for their support.

Ethical statements

This study does not involve any human or animal testing.

Authors contribution

Mr. Atul Kumar executed the work, Dr. D. D. Wadikar, Planning & Supervision; Mr. Santosh Pal-Processing support, Mr. D. K. Yadav-Analysis support; Dr. A. D. Semwal, Director, DFRL-Guidance to the work.

Conflict of interest

The authors declare that they do not have any conflict of interest.

References

[1] Shahbandeh M. *Global food spread market size from 2019 to 2024*. Available from: https://www.statista.com/statistics/1021617/global-food-spread-market-size/ [Accessed 14th January 2022].

[2] Statista. *Spreads - India*. Available from: https://www.statista.com/outlook/cmo/food/spreads-sweeteners/spreads/india [Accessed 5th January 2023].

[3] Kirse A, Karklina D, Muizniece-Brasava S. Consumer acceptance of new pulse spreads before and after sous vide treatment. *Journal of International Scientific Publications: Agriculture & Food*. 2016; 4: 104-114.

[4] AOAC. *Official method for Analysis*. 14th ed. Association of official Analytical Chemists. Washington; 1984.

[5] Okaka JC, Potter NN. Functional and storage properties of cowpea powder-wheat flour blends in breadmaking. *Journal of Food Science*. 1977; 42(3): 828-833.

[6] Jitngarmkusol S, Hongsuwankul J, Tananuwong K. Chemical compositions, functional properties, and microstructure of defatted macadamia flours. *Food Chemistry*. 2008; 110(1): 23-30.

[7] Sowbhagya HB, Florence-Suma P, Mahadevamma S, Taranathan RN. Spent residue from cumin-a potential source of dietary fiber. *Food Chemistry*. 2007; 104: 1220-1225.

[8] Aguilera Y, Esteban RM, Benitez V, Molla E, Martin-Cabrejas MA. Starch, functional properties, and microstructural characteristics in chickpea and lentil as affected by thermal processing. *Journal of Agricultural and Food Chemistry*. 2009; 57(22): 10682-10688.

[9] Bonczar G, Wszołek M, Siuta A. The effects of certain factors on the properties of yoghurt made from ewe's milk. *Food Chemistry*. 2002; 79(1): 85-91.

[10] Glibowski P, Zarzycki P, Krzepkowska M. The rheological and instrumental textural properties of selected table fats. *International Journal of Food Properties*. 2008; 11(3): 678-686.

[11] AOAC. *Official Methods of Analysis*. 17th ed. Association of official analytical chemists. Gaithersburg; 2000.

[12] Kaur M, Singh N. Studies on functional, thermal and pasting properties of flours from different chickpea (*Cicer arietinum* L.) cultivars. *Food Chemistry*. 2005; 91(3): 403-411.

[13] Avanza MV, Chaves MG, Acevedo BA, Añón MC. Functional properties and microstructure of cowpea cultivated in north-east Argentina. *LWT-Food Science and Technology*. 2012; 49(1): 123-130.

[14] Xu Y, Thomas M, Bhardwaj HL. Chemical composition, functional properties and microstructural characteristics of three kabuli chickpea (*Cicer arietinum* L.) as affected by different cooking methods. *International Journal of Food Science & Technology*. 2014; 49(4): 1215-1223.

[15] Larrea MA, Chang YK, Martinez-Bustos F. Some functional properties of extruded orange pulp and its effect on the quality of cookies. *LWT-Food Science and Technology*. 2005; 38(3): 213-220.

[16] Prentice JH. Rheology and texture of dairy products. *Journal of Texture Studies*. 1972; 3(4): 415-458.

[17] Chai X, Meng Z, Liu Y. Relationship between lipid composition and rheological properties of colloidal fat crystal networks: A comparative study using chemometrics. *LWT-Food Science and Technology*. 2020; 118: 108814.

[18] Radocaj O, Dimic E, Diosady LL, Vujasinovic V. Optimizing the texture attributes of a fat-based spread using instrumental measurements. *Journal of Texture Studies*. 2011; 42(5): 394-403.

[19] Aryana KJ, Resurreccion AV, Chinnan MS, Beuchat LR. Functionality of palm oil as a stabilizer in peanut butter. *Journal of Food Science*. 2003; 68(4): 1301-1307.

[20] Yeh JY, Phillips RD, Hung YC. Optimizing protein-and vitamin-fortified peanut spreads containing soybean or milk powder. *Journal of Food Quality*. 2003; 26(3): 243-256.

[21] Dubost NJ, Shewfelt RL, Eitenmiller RR. Consumer acceptability, sensory and instrumental analysis of peanut soy spreads. *Journal of Food Quality*. 2003; 26(1): 27-42.

[22] Mazaheri-Tehrani M, Yeganehzad S, Razmkhah-sharabiani S, Amjadi H. Physicochemical and sensory properties of peanut spreads fortified with soy flour. *World Applied Sciences Journal*. 2009; 7(2): 192-196.

[23] Dubost NJ. *Development and optimization of peanut soy spread*. MSc dissertation, University of Georgia. Athens, Georgia; 2001.