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Evaluation of Using Aquafaba as an Egg White Replacer in Sponge Cake Processing

Manal S. Helal and Shereen L. Nassef

Food Technology Research Institute, Agricultural Research Centre, Giza, Egypt.

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ABSTRACT

Aquafaba is a viscous liquid formed during cooking of kidney bean (Nebraska Variety) in water. This solution is now widely used by the vegan community and egg allergens as an egg replacer. The objective of this study was to evaluate the quality and possibility of egg white substitute with aquafaba in sponge cake. Physical characteristics, chemical composition and sensory properties of the cake samples were evaluated. The results demonstrated that foaming capacity values of aquafaba were 389.33% and egg white was 582.66%. Foam stability values were 85.49 % and 92.28 % in aquafaba and egg white, respectively. Water and oil absorption capacity of the aquafaba and egg white were 2.66 g/g 1.32 g/g, 2.94 g/g and 1.99g/g, respectively. The replacing of egg white by aquafaba did not greatly affect physicochemical parameters of the sponge cake made by using egg white. The cake made with aquafaba was slightly less moist than cake made with egg white (21.67%and 22.79%), had less height (4.21 and 4.47 cm), lower volume index (11.25 and 11.65 cm) and lower pH (7.95 and 8.02). Baking weight loss in aquafaba cake is 11.47% higher than egg white cake 9.09%. Sensory evaluation of aquafaba cake samples showed an acceptance and no negative effects in overall properties. The texture profile analysis of cakes prepared with aquafaba showed less hardness. The mineral composition (Zn, Cu, Mn, Ca, Fe, Mg and P) showed a high amount in aquafaba compared with egg white cake therefor, it could be is concluded that aquafaba is beneficial when instead of with egg white in eggless cake recipes.

Keywords: Aquafaba, Kidney bean, egg replacer, physicochemical properties, bakeries and sponge cake.

1. Introduction

As a result that egg protein is the second important food causing food allergy, hence a novel sort of substitute for strict vegetarian called "aquafaba" is acknowledged as a plant based emulsifier in numerous bread and pastries products rather than ordinary used egg white. Aquafaba, an eco-friendly by-product liquid separated from pulses cooking water (PCW), and minimize by-product waste from the pulse processing industry (Yue He *et al.,* 2021). Aquafaba has largely been used by the vegan community and the human who suffer from allergies to egg proteins which considered the second most serious of food allergens predominantly affecting children (Ruscigno, 2016).

"Aquafaba" in Latin, means bean water. It is simply the residual water obtained after cooking pulse in water. It contains different levels of soluble carbohydrates (simple sugars, polysaccharides), proteins, minerals and saponins that leach out during soaking and cooking. These compounds can achieve good foaming and gelling abilities (Stantiall *et al.,* 2018). Clinical studies conducted saponin have health benefits, where ability to lower cholesterol levels, blood lipids, and blood glucose response (Barakat *et al.,* 2015), the same author, also, reported that saponin consumption was shown to decrease the risk of cancer and has antioxidant capabilities. The reason for using aquafaba is that when the legumes are cooked, the starch inside them is absorbed by water and eventually breaks down into amylose and amylopectin and also protein and sugar are absorbed by cooking water together (Aquafaba, 2016). As a result, aquafaba is a significant use in food industry in many product formulation applications such as muffins Herranz *et al.,* (2016), bread and snacks Rachwa-Rosiak *et*

Corresponding Author: Manal S. Helal, Food Technology Research Institute, Agricultural Research Centre, Giza, Egypt.

al., (2015), cakes. Alifakı and Akıyan (2017), crackers, sponge cake and gluten-free bread, Mustafa *et al.,* (2018). Minerals content of legumes showed a significant reduction (18.99-39.50%) during soaking and cooking due to leaching of minerals into the used water (Huma *et al.,* 2008).

Moreover, recently, the viscous liquid 'aquafaba' produced from cooked legumes is considered an egg substitution in many foods due to nutritional and functional properties such as foaming, emulsifying, binding and thickening (Mustafa *et al.,* 2018). Recent research unveiled positive effects of aquafaba on the physiochemical properties of foods including confections, egg/gluten-free bakery products and mayonnaise (Yue He *et al.,* 2021).

The aim of this work was to study and evaluate the effect of using aquafaba *(kidney bean)* to replace egg white in sponge cake.

2. Materials and Methods

2.1. Materials

Kidney bean (Nebraska Variety) obtained from Horticulture Research Institute Agriculture Research Center, Egypt. Wheat flour extract 72%, sugar, Egg, salt, baking powder, apple vinegar, vanillin were purchased from Egypt local market.

2.2. Methods

2.1. Aquafaba preparation

2.1.1. Kidney Bean cooking water

Cooking water from Kidney Beans were obtained via process described by Stantiall *et al.,* (2018) Briefly, 16 hr. -soaking (in 1: 4 ratio) at room temperature was followed by boiling with 1:1.75 ratio (Kidney Bean: tap water) for an overall cooking time of 60 min. yielding about 0.54 parts of aquafaba per part of Kidney Bean. Tap water used was soft, thus having negligible impact on nutrient extraction and stored frozen at − 18 °C, then thawed in the refrigerator (+ 4 °C).

2.2.2. Aquafaba Functional Measurements

2.2.2.1. Foaming capacity and foam stability

Foaming capacity and foam stability were determined according to Liu *et al.,* (2010) and Martinez *et al.,* (2016) with some modification, 15 ml of aquafaba as egg replacer has been added in a 50 ml graduated cylinder then foamed using Braun MQ9047X MultiQuick 9 Hand blender - 1000 Watt for 2 min, then foam volume were measured at 0 min (VF_0) and after 30 min (VF_{30}). Foaming capacity (FC) and foam stability (FS) were calculated using these Equations 1and 2, respectively.

$$\% \text{ FC}=\frac{VF0}{VF30}\times 100 \quad (1)$$

$$\% \ FS = \frac{VF30}{VF0} \times 100 \quad \text{.......(2)}$$

2.3. Emulsion stability

Aquafaba emulsion stability (ES) was measure according to Martinez *et al.,* (2016). 5 mL from aquafaba was homogenized with 5 mL of corn oil by using Dihan Brand Homogenizer HG- 15A mixing at the highest speed for 2 min. immediately the emulsion was quantitatively transferred to a 10-mL graduated cylinder. The volume of aqueous phase separated from the emulsion after 30 min was recorded and emulsion stability was calculated using this equation (3).

$$\%ES = \frac{V_B - V_A}{V_B} \times 100 \quad \text{.......(3)}$$

Where, V_B is the aquafaba volume before homogenization (5 mL) and V_A is the aqueous phase volume after 30 min.

2.4. Water absorption capacity (WAC) and oil absorption capacity (OAC)

PCW and egg white samples were freeze-dried to test of WAC, OAC as a modified version of the method by Kaur and Singh (2005). 2.5 g of freeze-dried PCW were added to a 50-ml test tube with 20 g of distilled water and vortexed for 1 min to completely mix them. Solutions were then centrifuged using (Hermle Z 206 A) for 10 min at 1260 g. After centrifugation, the supernatant was discarded and the pellet weighed. WAC was calculated as the ratio of the pellet weight over the sample weight and expressed in g /g. For oil absorption capacity (OAC), distilled water was replaced with corn oil and values expressed in g /g (4).

$$\text{WAC or OAC} = \frac{\text{Hydrated residue weight}}{\text{Dry residue weight}} \quad \text{.......(4)}$$

2.5. Preparation of sponge cake

Foam was first produced using (Kitchen Braun MQ9047X MultiQuick 9 Hand blender - 1000 Watt) for whipping 110 mL of aquafaba or Egg white separated from whole egg (110 mL egg white) with 1 tsp. (3 g) of apple vinegar, starting on a low speed setting until most of the aquafaba or Egg white turned foamy and no liquid remained. The speed then was increased to the maximum setting and the mixture was whipped for 7 min. While mixing at the high-speed setting, 130 g of powdered sugar was added and the creamy mixture was whipped into a stiff peak for 3 min. In a separate bowl, flour (130 g) and baking powder (7 g) were blended, and then gently folded into the foam in three aliquots using a rubber spatula. Cake batter samples were then poured into baking pans and baked in a preheated conventional oven at 180 °C for 30 min. After cooking, pans were removed from the oven and cake in Fig. (1) inverted on a wire rack to cool at room temperature for 30 min prior to texture and color analysis. Cooled cakes were packed in polypropylene bags and frozen for further analyses (Mustafa *et al.,* 2018).

2.6. Determination of pH, moisture content and weight loss

Cake pH was determined by mixing (10 g) ground sample with 90 mL of distilled water and homogenizing for 1 min. Mixtures were held at 4 ^{0}C for 1 h to separate solid and liquid phases and supernatant pH was measured by PH meter Jenway 3510 made in UK. Cake moisture was determined as the difference in weight of cake samples before and after drying in an air oven at 100 °C For 16 – 18 h according to AACC method 44-19.01 (AACC, 2000). The baking loss (%) was determined by dividing the difference between the weight of batter before and after baking and cooling to the weight of the batter before baking (Diaz-Ramirez *et al.,* 2016).

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Fig.1: Representative samples of the produced cake: No.1 – Representing samples of cake produced from egg white No.2- Representing samples of cake produced from aquafaba

2.7. Cake expansion and volume index

Cake expansion (Height cm) and volume index were determined following Rahmati and Tehrani (2014) and AACC method 10-91.01 AACC, (2000). Baked cakes were cooled to room temperature and cut vertically through the center into two equal segments which were then divided into many slices (2.5 cm of thickness). The height of the face of each slice was determined at different positions and used to calculate cake expansion. Volume index was calculated by the following equation (5):

Volume index = B + C + D……………………………………………………………….…….(5)

Where C is the cake's height at the Centre, and B and D are the heights of the cake sample at the points 2.5 cm away from the center towards the left and right sides of the cake.

2.8. Water activity

Water activity of cakes was measured at zero time using a Rotronic Hygro Lab water activity meter EA10-SCs (Switzerland) at 25 ± 2ºC. Samples were crushed into small pieces and a representative sample was placed into plastic cups and measured one at a time.

2.9. Mineral profile

Samples were processed and the determination of minerals were analyzed. Microwave digestor (Multiwave GO Plus 50 HZ) was used prior to spectrophotometric analysis of the samples by MP-AES (Microwave Plasma -Atomic Emission Spectroscopy) (Agilent, Mulgrave, Victoria, Australia).

2.10. Color

The color of cake samples was determining $L*$ (lightness/darkness), $a*$ (redness/greenness) and $b*$ (yellowness/ blueness) parameters with a colorimeter (Model CR 400 Chromo meter, Konica

Minolta, Japan). Chroma and hue angle of cake samples were calculated from *a** and *b**. readings with three replications for each sample.

2.11. The texture profile analysis (TPA)

A Texture analyzer (BROOKFIELD CT3 TEXTURE ANALYSER operating instructions. Manual No.M08-372-C0113, Stable Micro Systems, USA) was used to measure the Texture profile of cakes in terms of hardness (N) Cohesiveness, gumminess (N), chewiness (mj), adhesiveness (mj),springiness (mm), and resilience of the sample. The sample (2.5 cm height and 4 cm diameter) were compressed twice to 40% of the original height using settings as text-TPA, probe-36 mm cylindrical, Pre-text speed -2 mm/s, post- text speed -2mm. The experiments were conducted under ambient conditions.

2.12. Sensory analysis of cake samples

Sensory analysis of cake samples was conducted by 10 well trained panelists were selected based on their interest, non-smoker and non-food allergic, from the staff of Baking and Pastry Department, Food Technology Research Institute, Agricultural Research Center. The sensory analysis was performed under daylight room conditions. The scoring scheme was established as mentioned by **Lee, (2015)** as follows: color, taste, flavor, appearance and overall acceptability degrees.

Statistical analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM Corp., Armonk, NY). Mean comparisons were made by analysis of variance (ANOVA) and comparisons of the means of two groups. Statistical significance was accepted at $P < 0.05$. Data are presented as mean ± standard deviation (SD) (n = 3).

3. Results and Discussion

Aquafaba produced from cooked legumes is considered an egg substitutier in many foods due to nutritional and functional properties (Mustafa *et al.,* 2018).

Aquafaba liquid has moisture content (95.33 %), protein (1.23 %), ash (0.77 %), and Fat was not detected. Shim *et al.,* (2018), the egg white content of water 85.1 %, protein 11.16%, fat 0.02% and ash was 0.67 % these results similar to Cegielska *et al.,* (2010).

Table 1: Chemical Composition of Egg White and Aquafaba on wet weight basis %.

Nutrients	Water	Protein	Fat	Ash
Egg white	85.1 ±0.132	11.16 ±0.050	0.02 ±0.010	0.67 ±0.010
Aquafaba	95.33 ±0.097	1.23 ±0.017	not detected	0.77 ±0.015

Each value is represented Mean of 3 replicates ± SD

The foam properties of the egg white and aquafaba used in the cake formulation are shown in Table (2).Foaming capacity values of Aquafaba were 389.33 % and egg white 582.66 %. Foam stability values 85.49 % and 92.28 %. Aquafaba and egg white respectively. Also emulsion stability of aquafaba 65.33 and egg white 84.97. In this table aquafaba has a lower foaming capacity and stability than egg white but the foam stability of the aquafaba showed similar characteristics compared to the egg.

Martinez *et al.,* (2016), reported that normally, protein foam capacity increases with time and then after maximum capacity is achieved, it decreased due to protein network breakdown Mine and Nilgün (2020), Buhl *et al.,* (2019) and Stantiall *et al.,* (2018) mentioned that egg white has significantly higher foaming capacity compared to aquafaba. Whipping aquafaba for at least 5 min is necessary to obtain foaming capacity comparable to egg white (Mustafa *et al.,* 2018). Cooking for prolonged periods might increase cell wall breakdown and transfer of fat to the cooking water which in turn reduces foaming capacity. Table (2) shows significant difference between egg white and aquafaba in Emulsion stability. Buhl *et al.,* (2019) found that the emulsions made with aquafaba from canned chickpea exhibited a significantly higher emulsion capacity and stability than emulsion

prepared by egg white powder with a pH from (3-8.5).WAC in aquafaba (about 2.66g/g), was higher value than egg white (1.32/g).The OAC value was (2.94) significantly higher than egg white,(1.99g/g) El-Adawy (2002) and Du *et al.,* (2014) reported that water soluble polysaccharides in Kidney bean pulses caused absorption and binding oil properties through their hydrophobic sites.
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Table 2: Physical properties of Egg White and Aquafaba.

Sample	Foam Capacity (%)	Foam stability (%)	Emulsion stability (%)	Water absorption capacity (g/g)	oil absorption capacity (g/g)
Egg white	582.66± 2.52	92.28±1.99	84.97±1.34	1.32±0.012	1.99±0.029
Aquafaba	389.33± 4.04	85.49± 1.60	65.33±1.53	2.66±0.076	2.94±0.053

Each value is represented Mean of 3 replicates ± SD

Physicochemical properties of sponge cakes prepared with Egg white and aquafaba are represent in Table (3).The replacing of egg white by aquafaba did not greatly affect physicochemical parameters of the sponge cake. The cake made with aquafaba was slightly lower pH (7.95 and 8.02), less moist than cake made with egg white (21.67% and 22.79%), less height (4.21 and 4.47 cm), lower volume index(11.25 and 11.65 cm),these results agree with Mine and Nilgün, (2020) and Buhl *et al.,* (2019).

Therefore, the foam collapses under heating before reaching the protein denaturation temperature. These phenomena may also due to the lower height and volume index seen in aquafaba cakes compared to cakes prepared with egg white utilizing aquafaba as an egg replacer. Baking loss value of aquafaba cake is higher than egg white cake, this baking loss values can be explained by the fact that the egg-containing cake formulations have a higher water binding capacity than the formulations prepared with egg substitution (Ratnayake *et al.,* 2012). Water activity showed in aquafaba was lower than egg white cake. Water activity refers to the amount of unbound water in foods which can be easily evaporated and consumed by microorganisms. Majzoobi *et al.,* (2018) reported that the cakes with higher water activity have shorter shelf-life mainly due to the microbial growth.

Table 3: Physicochemical properties of sponge cakes prepared with Egg white and aquafaba.

Property	Egg white cake	Aquafaba cake
pH	8.02± **0.08**	7.95 ± 0.05
Moisture content (%, wb)	22.79 ± 0.19	21.67 ± 0.21
Volume index (cm)	11.65 ±0.050	11.25± 0.05
Height (cm)	4.47± 0.06	4.21±0.02
Baking weight loss (%, w/w)	9.09 ± 0.10	11.47± 0.05
Water activity a_w	0.78 ± 0.002	0.74 ± 0.002

No Significant difference at $P < 0.05$.
Each value is represented Mean of 3 replicates ± SD

Sensory properties of cake samples in Table (4), showed that cake prepared from aquafaba enhanced the flavor but other properties was higher in egg white cake. According to overall acceptability properties, were observed (in table (4) no negative effects were observed. So it is recommended that consumers interested in utilizing aquafaba as an egg replacer in cake similar observations were reported when sponge cake was made with other egg white replacements (Rachwa-Rosiak *et al.,* 2015 and Lee, 2015).

Table 4: Sensory characteristics * of cake prepared by using aquafaba as an egg white replacer.

Sample	Appearance	Texture	Flavor	Taste	Color	Overall acceptance
Egg white cake	9.65±0.34	9.45±0.64	9.1±0.52	9.5±0.24	9.7±0.35	9.53±0.16
Aquafaba cake	9.35±0.34	9.35±0.41	9.65±0.47 *	9.4±0.32	9.6±0.32	9.46±0.28

* Significant difference at $P < 0.05$.
Each value is represented Mean of 3 replicates ± SD

External color is an important factor in the perception of cake quality as given by *L,a,b* H hue angle and Chroma. The L parameter is an indicator of cake darkening. The cake with aquafaba and egg white showed in Table (5) L values decreased than cake prepared by white egg white cakes. Both chroma and hue angle values of cake color showed differences between aquafaba and egg white cakes, these results agree (Mine and Nilgün, 2020). Aquafaba contains simple sugars and polysaccharides which contribute to Maillard and caramelization reactions (Shim *et al.,* 2018). This explains the differences in color between both cakes made with aquafaba and egg white. Similar observations were reported when sponge cake was made with other Egg white replacements aquafaba (Rachwa-Rosiak *et al.,* 2015 and Lee, 2015).

Table 5: Color parameters * of sponge cakes prepared with egg white and aquafaba.

Color	L	a	b	C	H
Aquafaba cake	55.35± 1.84	0.99± 1.91	30.35±10.17	32.9±10.96	81.95±10.28
Egg white cake	59.89±3.18*	1.94±1.61*	33.94±9.25*	34.76±9.26*	85.55±3.43*

* Significant difference at $P < 0.05$.
Each value is represented Mean of 3 replicates ± SD

Unique foaming, emulsifying and heat coagulation properties of egg white protein play an important role in cake volume and texture as reported by Ashwin*i et al.,* (2009). In (Table 6), cake made by aquafaba had low hardness springy, cohesive, resilience, adhesiveness and gumminess than egg white cakes values. In this study aquafaba has been added as a foaming and texturizing agent to replace the egg white in this application. On the other hand, Mustafa *et al.,* (2018) reported that the color, appearance, and texture of aquafaba eggless sponge cake were similar to those of sponge cake made with egg white. Herranz *et al.,* (2016) found that chickpea flour decreased the springiness, cohesiveness, chewiness and specific volume of gluten-free muffins. However, those characteristics were improved by adding xanthan gum.

Table 6: Instrumental texture profile * analyses

Texture profile	Egg white cake	Aquafaba cake
Hardness (N)	30.89 ± 0.12	17.65± 0.17*
Chewiness (mJ)	237.35± 0.49	94.4± 0.50*
Springiness (mm)	9.15± 0.11	7.14± 0.12*
Cohesiveness (ratio)	0.84± 0.10	0.74± 0.015*
Resilience	0.38± 010	0.30± 0.010*
Adhesiveness(mJ)	0.010± 010	0.020± 010*
Gumminess (N)	26.25±0.060	13.15± 0.053*

* Significant difference at $P < 0.05$.
Each value is represented Mean of 3 replicates ± SD

Table (7) identified that the mineral composition of Zn, Cu, Mn, Ca, Fe, Mg and P presented in a high amount in aquafaba and its cake compared with egg white and its cake. Mineral profile of PCW should be considered when evaluating food applications (Whelton *et al.,* 2007). Previous studies showed leaching of minerals from pulses to cooking water upon boiling (Damian *et al.,* 2018). The ratios of sodium to potassium (Na/K) and calcium to phosphorus (Ca/P) are shown in Table (7). Na/K ratio less than one is recommended. Hence, all samples would probably reduce high blood pressure disease because they had Na/K less than one. Phosphorus is always found with calcium in the body, both contributing to the blood formation and supportive structure of the body (Ogunlade *et al.,* 2005). If the Ca/P ratio is low (low calcium, high phosphorus intake) more than the normal amount of calcium may be loss in the urine, decreasing the calcium level in bones. Food is considered “good” if the ratio is above one and “poor” if the ratio is less than 0.5 (Nieman *et al.,* 1992). The Ca/P ratio in the present study showed 1.424 in (egg white) to 1.863 in aqua cakes indicating they would serve as good sources of minerals for bone formation. Although minerals may affect food texture due to interactions with macromolecules. Calcium, in particular, have been shown to modulate hydrocolloids functionality in food gels (Nussinovitch *et al.,* 1990).

Table 7: Mineral Profile * raw material and sponge cakes prepared by egg white or Aquafaba (mg/100g).

Mineral content	Zn	Cu	Mn	Na	Ca	K	Fe	Mg	P	Na/K	Ca/P
Egg white	0.016 ±0.002*	0.062 ±0.002*	0.024 ±0.004	88.02 ±1.38	17.8 ±0.23	214.27 ±1.34	0.077 ±0.02	10.03 ±0.07	12.5 ±0.415	0.41	1.42
Aquafaba	0.273 ±0.03*	2.377 ±4.004	0.423 ±0.03*	44.22 ±1.6*	95.8 ±8.26*	151.76 ±0.81*	0.61 ±0.02*	31.52 ±0.47*	55.16 ±5.29*	0.29	1.74
Aqua cake	1.070 ±0.02*	0.187 ±0.006*	0.253 ±0.006*	82.70 ±0.42*	61.96 ±0.85*	141.43 ±0.66*	0.93 ±0.015*	25.63 ±0.429*	33.25 ±0.05*	0.59	1.87
Egg cake	0.943 ±0.02*	0.150 ±0.01*	0.220 ±0.01*	124.16 ±0.71	49.04 ±1.08	299.98 ±4.040	0.51 ±0.01*	21.419 ±0.409	27.58 ±0.14	0.41	1.78

* Significant difference at $P < 0.05$.
Each value is represented Mean of 3 replicates ± SD

Conclusion

A novel formulation of eggless sponge cake was developed using aquafaba resulting from cooking kidney bean in water. Aquafaba, from by- product considered a Value-Added substance in cake preparations.

References

AACC. 2000. American Association of Cereal Chemists). 11th ed. St. Paul, MN: AACC International.

Alifakı, Y.O., and O. S¸akıyan, 2017. Dielectric properties, optimum formulation and microwave baking conditions of chickpea cakes. Journal of Food Science and Technology, 54: 944–953.

Aquafaba, 2016. The official aquafaba website. http://aquafaba.com

Ashwini, A., R. Jyotsna, and D. Indrani, 2009. Effect of hydrocolloids and Emulsifiers on the rheological, microstructural and quality characteristics of eggless cake. Food Hydrocolloids, 23: 700–707.

Barakat, H., V. Reim, and S. Rohn 2015 Stability of saponins from chickpea, soy, and faba beans in vegetarian, broccoli-based bars subjected to different cooking techniques. Food Res. Int.,76: 142–149.

Buhl, T.F., C.H. Christensen, and M. Hammershøj, 2019. Aquafaba as an egg white substitute in food foams and emulsions: Protein composition and functional behavior. Food Hydrocolloids, 96(October 2018): 354–364.

Cegielska, R.R., G. Lesnierowski, T. Szablewski, and J. Kijowski, 2010. Physico-chemical properties and antibacterial activity modified egg white-lysozyme. Eur Food Res Technol., 231(6):959-64.

Damian, J.J., H. Siyu, and S. Luca, 2018. Phytochemical content and emulsifying ability of pulses cooking water. European Food Research and Technology volume 244, pages1647–1655.

Diaz-Ramirez, M., G. Calderón-Domínguez, M. García-Garibay, J. Jimenez-Guzman, A. Villanueva-Carvajal, M. Salgado-Cruz, A. Daniel, and E. Ramírez, 2016. Effect of whey protein isolate addition on physical, structural and sensory properties of sponge cake. Food Hydrocolloids, 61:633-639.

Du, S.K., H. Jiang, X. Yu and J.L. Jane 2014. Physicochemical and functional properties of whole legume flour. LWT Food Sci. Technology, 55(1):308–313.

El-Adawy, T.A., 2002. Nutritional composition and antinutritional factors of chickpeas (*Cicer arietinum L.*) undergoing different cooking methods and germination. Plant Foods Hum. Nutr., 57(1):83–97.

Herranz, B., W. Canet, M.J. Jim_enez, R. Fuentes, and M.D. Alvarez, 2016. Characterisation of chickpea flour-based gluten-free batters and muffins with added biopolymers: rheological, physical and sensory properties. International Journal of Food Science and Technology, 51: 1087–1098.

Huma, N., F.M. Anjum, S. Sehar, M.I. Khan, and S. Hussain, 2008. Effect of soaking and cooking on nutritional quality and safety of legumes. Nutrition and Food Science, 38(6): 570-577.

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

Lee, J.H., 2015. Physicochemical and sensory characteristics of sponge cakes with *Rubus coreanus* powder. Preventive Nutrition and Food Science, 20:204–209.

Liu, S., C. Elmer, N.H. Low, and M.T. Nickerson, 2010. Effect of pH on the functional behavior of pea protein isolate-gum Arabic complexes. Food Research International, 43(2): 489–495.

Martinez, M., A.K. Stone, A.G. Yovchev, R. Peter, A. Vandenberg, and M.T. Nickerson, 2016. Effect of genotype and environment on the surface characteristics and functionality of air-classified faba bean protein concentrates. European Food Research and Technology, 242: 903–1911.

Majzoobi, M., M.M. Mohammadi, G.M. Mesbahi, and F. Asgar, 2018. Feasibility study of sucrose and fat replacement using inulin and rebaudioside A in cake formulations. J Texsture Stud., 49:468–475.

Mine, A. and E. Nilgün, 2020. Possibility of using 'chickpea aquafaba' as egg replacer in traditional cake formulation. Harran Tarım ve Gıda Bilimleri Dergisi, 24(1): 1-8.

Mustafa, R., He, Y., Y.Y. Shim, , and M.J. Reaney, 2018. Aquafaba, wastewater from chickpea canning, functions as an egg replacer in sponge cake. International Journal of Food Scirnce & Technology, 53(10): 2247-2255. https://doi.org/10.1111/ijfs.13813.(2018).

Nieman, D.C., D.E. Butterworth and C.N. Nieman, 1992. Nutrition, 237-312, WmC. Brown Publishers. Dubugye, USA.

Nussinovitch, A., I.J. Kopelman, and S. Mizrahi, 1990. Effect of hydrocolloid and minerals content on the mechanical properties of gels. Food Hydrocoll., 4(4):257–265.

Ogunlade, I., O. Olaofe, and I. Fadare, 2005. Chemical composition, amino acids and nutritional properties of selected seafoods. J. Food Agric. Environ., 3: 130-133.

Rachwa-Rosiak, D., E. Nebesny, and G. Budryn, 2015. Chick peas composition, nutritional value, health benefits, application to bread and snacks: A review. Critical Reviews in Food Science and Nutrition, 55: 1137–1145.

Rahmati, N.F. and M.M. Tehrani, 2014. Replacement of egg in cake: effect of soy milk on quality and sensory characteristics. Journal of Food Processing and Preservation, 39: 574–582.

Ratnayake, W.S., B. Geera, and D.A. Rybak, 2012. Effects of egg and egg replacers on yellow cake product quality. Journal of Food Processing and Preservation, 36(1):21-29. https://doi.org/10.1111/j.1745-36(1):21-29.

Ruscigno, M., 2016. Guide to Eating Egg-Free. Today's Dietitian, 18, 36 41. Aquafaba, wastewater from chickpea canning, functions as an egg replacer in sponge cake. International Journal of Food Science and Technology, 53: 2247–2255.

Shim, Y.Y., R. Mustafa, J. Shen, K. Ratanapariyanuch, and M.J.T. Reaney, 2018. Composition and properties of aquafaba water recovered from commercially canned chickpeas. J. Vis. Exp. 132, e56305.

Stantiall, S.E., K.J. Dale, F.S. Calizo, and L. Serventi, 2018. Application of pulses cooking water as functional ingredients: The foaming and gelling abilities. European Food Research and Technology, 244(1): 97–104. https://doi.org/10.1007/s00217-

Whelton, A.J., A.M. Dietrich, G.A. Burlingame, M. Schechs, and S.E. Duncan, 2007. Minerals in drinking water: impacts on taste and importance to consumer health. Water Sci. Tech., 55(5):283–291.

Yue He., M.Venkatesh, Martin J.T. Reaney, and Rana Mustafa2021. Aquafaba, a new plant-based rheological additive for food. Trends in Food Science & Technology, 111: 27-42.