'AQUAFABA'- A DYNAMIC REVOLUTIONARY APPROACH TOWARDS VEGANISM AND FOOD WASTE REDUCTION

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Abstract: *Food wastage is a burning issue today that has put several lives to death-bed due to malnourishment. Aquafaba, one such example, is a multifaceted, versatile ingredient which can be incorporated into numerous dishes so as to enhance the nutritional, sensory and textural profile of the food product. It is in trend today because of the certain reasons like egg allergy, health concerns, religious beliefs, sustainability issues, dietary preferences, etc. The youth is now getting more inclined towards the concept of sustainable diets like Veganism. The concept of food waste management is an integrated approach of not only reducing the amount of food wastage but also increasing its availability, recycling & reusing its discarded forms to provide it to the people. By utilizing this by-product, food manufacturers can minimize resource waste, lower production costs, and reduce reliance on animal-based ingredients, thus promoting environmental sustainability. Its increasing adoption in vegan and plant-based diets also aligns with global efforts to reduce the ecological footprint of food production. The review aims to explain that, aquafaba have the potential to provide nutrient rich foods and prevent food wastage at the same time. Its proximate composition unfurls the potential of a good fat replacer in bakery industry.*

Keywords: *Dietary preferences, Egg allergy, Environmental sustainability, Fat replacer, Food wastage, Malnourishment.*

1. INTRODUCTION

Pulses are nutritive foods which fulfil the daily needs of the people throughout the world. They are referred as the "common man's meat" because they contain fairly equivalent protein reservoir in them. Pulses are nutritionally rich foods that have diversified uses in the culinary industry domestic and commercial level [1]. India is the largest producer, consumer and importer of Pulses and Legumes in the world [2]. However, pulses stands at a special position in the Indian diet because they significantly reduce protein deficiency, when animal source foods are limited because of affordability, perishability and cultural beliefs [3]. Food and Agriculture Organization (FAO) declared 2016 as the "International Year of Pulses" to enhance the public awareness regarding its usage, sustainable production, global food security and nutritional benefits [4].

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Nowadays the concept of including vegetarian and specifically vegan foods in the diet is the new trend. Vegan foods comprise of all such food items that are plant-based and have no association with animals in the due process of growing and bringing it to the plate. These exclude products obtained from animals like meat, poultry, eggs, seafood, milk and other dairy products. Some vegans not only pay attention to their food choices but also they do make sure that they avoid wearing animal coat fabrics and materials on their body [5]. The increasing popularity of Veganism is evident from the fashion, food, cosmetics, household industry where the products are manufactured; keeping veganism in mind [6]. According to a survey conducted in 2022, 24% of India's total population is vegetarian and 9% of them are purely vegans; the count increasing day by day [7]. The vegan diet has the advantages over other diets in terms of healthism, environmentalism, and religionism. People following vegan diet have much reduced issues of obesity, diabetes, hypertension, mortality, osteoporosis and malnutrition. There is also a marked reduction observed in the medications prescribed to them for different health conditions and also the quality of life improved. Some moderate-quality evidences also prove that there are certain micronutrients, which are deficit in the vegan subjects [8]. According to Polaris Market Research 2020, global plant-based market worth 11.1 USD in 2019 is expected to be valued at 35.8 million USD by 2027. The global, national as well as regional market provides with the widespread options for vegan food products, beverages and nutritional supplements too. The theory of veganism justifies the use of each and every component of the plant and its associated dimensions to the fullest. This also helps to reduce the waste generated at any of the cultivation, processing and utilisation phase [9].

Food wastes are such items that may be edible or inedible but are discarded at any phase of cultivation, processing or handling due to certain reasons. They are potentially usable foods, nevertheless gets thrown away as expired foods, leftovers, rotten, unripe, over ripe, low quality, poor packaged, inappropriately stored, infected and infested foods [10]. According to FAO, a total of 1.3 billion tonnes of edible food is wasted annually worldwide and India has a share of about 69 million metric tonnes of food wastage [11]. The Global Hunger Index 2022 ranks India on 107 out of 121 countries in terms of hunger and lack of proper supply of food to the people [12]. Food waste and its effective utilisation has been a delicate issue since pre-historic times and has continued to be a crucial concern today as well. The primary aspect of food waste management is explicitly explained in the Goal 12 of Sustainable Development Goals (SDGs)- "Ensure sustainable consumption and production patterns" and Goal 1 of Millennium Development Goals (MDGs) which portrays the concept of "Eradicate extreme poverty and hunger" [1, 13]. Food waste management is an integrated approach of reducing the amount of food wastage, increasing its availability, recycling & reusing the different discarded forms of food and providing it to the entire population. Indeed, Food availability can be increased by preventing food losses that may contribute for an efficacious conduct of food supply chain throughout [14]. When the two concepts i.e., veganism and food waste combines, there emerges a distinctive and over the top food waste ingredient that owns the limelight in the referred as "Aquafaba".current times, which is

'Aquafaba' is a white coloured, turbid leftover liquid in which beans or legumes (mainly chickpeas) has been soaked and boiled for some time duration. Soaked legumes or seeds minus the starchy water equals aquafaba. It is an eco-friendly by-product which is obtained by soaking the legumes in water, boiling it at a specific temperature and under controlled pH conditions. It is emerging as a vegan product that acts as an egg replacement, nevertheless providing all the similar necessary textures, flavours and nutritive values [15, 16]. Although several types of beans and legumes like green mung beans, red kidney beans, horse gram, lima beans, green peas, black beans, white beans, lentils, broad beans, flat beans, soy beans, navy beans; but the most commonly used is chickpeas or garbanzo beans [17]. Apparently, aquafaba is regarded as the waste water in literal terms abut in real it has proven to be a golden liquid which when utilised effectively, occupies a major ingredient in the food and confectionary industry. It is an economical food item which enlists itself in promoting the ideology of sustainable development [18]. The commercial production of the canned beans water is a consistent process that yields a dairy free, cruelty free [19], plant-based, unique food alternative to eggs [14]. It is a multifunctional, leftover legume cooking water that has foaming, gelling, emulsifying, sparkling, thickening, water holding and fat replacing properties in them [16, 20].

2. MATERIALS and METHODS

A narrative review approach was followed to analyse the research articles to frame a review paper that explains the concept chosen. Google Scholar, Research Gate, Elsevier were surfed and almost 75 relevant papers were selected to understand, analyse and paraphrase. The keywords used for the same were Aquafaba, Shelf-life, Vegan, Global hunger index, Legumes, Chickpea. The keywords used for the same were Aquafaba, Shelf-life, Vegan, Global hunger index, Legumes, Chickpea.

3. RESULTS and DISCUSSION

History of Aquafaba

Aquafaba is derived from latin origin and is composed of two words 'aqua' and 'faba' meaning water and Fabaceae family of legumes respectively [16, 21, 22]. Aquafaba's discovery dates back to 2014 in which groups of French people have contributed. Initially, Joel Roessel whipped the 'red bean' water and used it for baking purpose and popularized it in his blogs. He concluded that it had similar texture of egg white and may give the same consistency in foods. He also owns the credit of naming it as 'Aquafaba'. A few literatures mention that this term was coined by Goose. Later, Goose Wohlt searched for suitable vegan options, and disseminated the idea of Aquafaba and also posted recipes using it as an ingredient. They used social media platforms to spread the concept of Aquafaba and promote it as an egg replacer [19]. Miyoko Schinner in 2011 invented linen gel meringue, which was supposed to be similar to aquafaba but had an off-flavour of flax seeds. In August 2012, meringue from saponin extract was made; but it also had an unpleasant sensory quality [9]. Later, Dan Barber, a famous restaurateur started incorporating it in various dishes and compiling its cook books [23].

Preparation of aquafaba

According to a study, 100 g chickpeas were soaked in distilled water for 16 hours at 4^{o} C and were later boiled and cooled. The water separated, was churned and foam was obtained. Aquafaba production involves 3 major steps: soaking of the beans, draining the water to remove the anti-nutritional components present like phytates, saponins, oxalates [4] and lastly, high pressure cooking to get the desired gelatinous liquid [24, 25]. Wiekzorek et al. advocated for the methodology of soaking the beans in hot water for 2 hours because it showed better results [27]. Serventi, L. (2020) explained the procedure for chickpeas boiling at 98^{o} C for 30 minutes [28]. An author explained that the 300 g chickpeas and 6 g salt should be soaked in 2 litre of distilled water for 12 hours; it is then pressure cooked for 35 min and strained [18]. Muhialdin et al. (2021) procured best quality aquafaba by soaking the legume in water for 24 hours and boiling it at 120º C for 35 minutes [29]; whereas Silva et al. (2020) soaked 2 kg Kabuli in 6 Litre water and cooked it for 20 minutes in a pressure cooker and lastly strained the aquafaba liquid [30]. Some authors promoted the method involving soaking of chickpeas in 500 mL distilled water (1:5 ratios) for boiling at 98º C for 30 minutes. The water received after straining the beans was refrigerated at 4º C for 12 hours [8, 31]. In another research paper, the authors soaked the chickpeas in 1:3 ratios distilled water at 4º C for 16 hours and was pressure cooked in 1:2 ratio distilled water at 115-118º C for 30 minutes. Lastly, the aquafaba liquid was separated by using a strainer [20]. Shim et al. (2021) prepared the soybean aquafaba in two different ways: (1) with pre-soaking in distilled water for 16 hours at 4º C & cooking for about 30 minutes and (2) without pre-soaking under pressure cooking in a sealed glass jar at 115-118º C. He used black, yellow and white soybeans for the preparation of the same [32].

Some studies depicted the usage of both conventional and ultrasound soaking process for chickpeas, kidney, broad, lentils, beans and green peas. The soaked pulses are cooked at an optimum temperature of 95º C for 26 min (broad and kidney beans), 20 min (chickpea and bean), 14 min (pea) and 6 min (lentil) [32, 33]. On the other hand, the procedure of 1:3 ratios soaking and cooking for 20 minutes to obtain better results were found convenient [34].

Figure 1. Ingredients of Aquafaba

Nutritional profile of Aquafaba

Some reports have reported 1.5/100 g protein, 0.5/100 g ash, 94/100 g water, 4/100 g carbohydrates and no traces of fat in the prepared aquafaba [35, 36]. Raikos et al. (2019) outlined the aquafaba composition as 1.27/100 g protein, 0.44/100 g ash, 2.64/100 g carbohydrates, 0.64/100 g sugars and 17 mg/100 g sodium; no fat was present [37]. Proteins are an essential component of beans and legumes, because of which the aquafaba liquid or foam also possesses ample protein quantity that makes it nutritious. This study showcased that 1 litre of canned liquid contains 13 g of protein in it [12]. As per the reports of two authors, the protein content of aquafaba in dry state contributed about 22-34% protein [24]. An author studied on chickpeas, cowpea and horse gram cooking water which had 1.50%, 2.04%. 0.50% protein content respectively [4]. The cowpea water had the highest radical scavenging or anti-oxidant properties followed by chickpeas and horse gram [38]. Aquafaba as a whole is rich in micronutrients like manganese, potassium and copper [39].

Figure 2: Foamy aquafaba

Table 1: Nutritional profile of Aquafaba [32]

Nutrient	Amount (per 100 g)
Ash	0.44 g
Water	94 g
Sugar	0.64 g
Sodium	17 mg
Protein	1.5 g
Fat	0 g
Carbohydrate	2.64 g

Anti-nutritional components

Phytatic acids and Tannins are the major anti-nutritional compounds present in the aquafaba liquid thereby reducing the protein complexes.[21] A few other authors too reported the pre-soaking method to reduce the nutritional quality, thereby affecting the protein digestibility complexes [41, 42]. In an aquafaba sample, the carbohydrate content deteriorated with pre-soaking and the presence of oligosaccharides led to digestive problems like flatulence, bloating and acid reflux [43, 44].

Shelf-life enhancing procedures

Aquafaba has a huge water content which is why; it is very prone to microbial decay thus reducing its shelf life. The high water activity makes it unsuitable for storage and thus it is mandatory to devise out techniques to increase the shelf life. This plant-based protein has numerous health benefits, which makes it a deserving ingredient to have all the focus upon it and figure out ways to increase its storage possibilities.

The foremost popular methodology of aquafaba storage is Foam-mat drying. It is a procedure which involves drying out the liquid content until when it reaches at a powder stage and the entire amount of water is discarded out. It is a suitable technique for semi-liquid to liquid materials and keeps intact the freshness in it. The best quality material was received when the liquid aquafaba was passed under the temperature of 70º C. the foaming agents used were carboxymethylcellulose (CMC), Na-alginate, polydextrose, and whey powder [45]. A study reported several drying techniques (spray drying, freeze drying, oven drying, rotovap drying, and vacuum pressure drying) to enhance the shelf life. Among these, spray and freeze drying methods are most acceptable ones for home and industrial usage [24]. Chickpea cooking water had 92.63% moisture content, which was reduced to optimal state at 80º C for 4 hours to have better storage conditions [38]. Stasiak et al. (2023) mentioned about storing it in freeze condition in glass jars [46] and some other authors advocated that the best way to store aquafaba is by drying it [31, 39].

Culinary importance of Aquafaba

Figure 3: Aquafaba incorporated recipes

1. Preparation of meringues, mayonnaise, hollaindaise sauce, whipping cream, salad dressings, ice-cream, and yoghurt [25, 47]
2. Aquafaba can be used as a fat replacer in the preparation of bakery products like sponge cake, macaroons [40, 48]
3. Used as a texturizer, emulsifier, foam and thickener [4]
4. It is multifunctional, leftover legume cooking water that has foaming, gelling, emulsifying, sparkling, thickening, water holding and fat replacing properties [39]
5. Its usage does impart a remarkable impact on environment in terms of minimizing food waste loss [13, 49]

4. CONCLUSION

Aquafaba not only fulfils the gap between the problem of food wastage and food hunger index but also unfurls a new dimension in the vegan research sector. Legumes are the raw materials of an interesting food by-product, Aquafaba, which has several utilities in the culinary industry. More alternatives for its shelf life increment could be devised with adequate research for future studies. In addition to it, more culinary applications can be done and the market for vegan industry could be flourished. Standardization of the aquafaba production process should also be a priority for future research. The origin of aquafaba is ambiguous but that should not be a hindrance in promoting its usage. However, some non-conventional legumes must also come in play and participate in more nutritious food development to overcome protein malnutrition. Food availability can be increased by preventing food losses that may contribute for an efficacious conduct of food supply chain throughout. Aquafaba and its related concepts have achieved a great importance in a very less time and are known to be a fascinating frontier of research currently.

REFERENCES

1) Gustavsson J, Cederberg C, Sonesson U, et al. *Global food losses and food waste – Extent, causes and prevention*. FAO; 2011. https://www.fao.org/3/mb060e/mb060e.pdf
2) Von Grebmer K, Bernstein J, Wiemers M, et al. *GLOBAL HUNGER INDEX FOOD SYSTEMS TRANSFORMATION AND LOCAL GOVERNANCE*. 2022. https://www.globalhungerindex.org/pdf/en/2022.pdf
3) APEDA. Pulses. https://apeda.gov.in/apedawebsite/SubHead_Products/Pulses.html. 2013.
4) Athira D., Chinju B., Gopika B. Studies on the functional properties of legume and pulse cooking water. *J Pharm Innov*. 2022; 11(7):4692-4704.
5) Vartak N.A.A., Tiwari N.A.D., Rana N.K.P. Development of vegan, gluten-free macarons using Artocarpus heterophyllus Lam. (jackfruit) incorporated with wheatgrass powder. *Int J Sci Res Arch.* 2023; 8(1):845-852. doi:10.30574/ijsra.2023.8.1.0172.
6) He Y., Meda V., Reaney M.J.T., Mustafa R. Aquafaba, a new plant-based rheological additive for food applications. *Trends Food Sci Technol*. 2021; 111:27-42. doi:10.1016/j.tifs.2021.02.035.
7) Alsalman F.B., Tulbek M., Nickerson M., Ramaswamy H.S. Evaluation and optimization of functional and antinutritional properties of aquafaba. *Legum Sci*. 2020; 2(2). doi:10.1002/leg3.30.
8) Aslan M., Ertaş N. Foam drying of aquafaba: Optimization with mixture design. *J Food Process Preserv*. 2021; 45(3). doi:10.1111/jfpp.15185.
9) John A.T., Makkar S., Swaminathan S., et al. Factors influencing household pulse consumption in India: A multilevel model analysis. *Glob Food Secur*. 2021; 29:100534. doi:10.1016/j.gfs.2021.100534.
10) Damian J.J., Huo S., Serventi L. Phytochemical content and emulsifying ability of pulses cooking water. *Eur Food Res Technol*. 2018; 244(9):1647-1655. doi:10.1007/s00217-018-3077-5.
11) Baik B., Han I.H. Cooking, roasting, and fermentation of chickpeas, lentils, peas, and soybeans for fortification of leavened bread. *Cereal Chem*. 2012; 89(6):269-275. doi:10.1094/cchem-04-12-0047-r.
12) Buhl T.F., Christensen C.H., Hammershøj M. Aquafaba as an egg white substitute in food foams and emulsions: Protein composition and functional behavior. *Food Hydrocoll*. 2019; 96:354-364. doi:10.1016/j.foodhyd.2019.05.041.
13) Crawford K., Tyl C., Kerr W. Evaluation of processing conditions and hydrocolloid addition on functional properties of Aquafaba. *Foods*. 2023; 12(4):775. doi:10.3390/foods12040775.
14) Edleman D., Hall C. Impact of processing method on AQF functionality in bakery items. *Foods*. 2023; 12(11):2210. doi:10.3390/foods12112210.
15) Frias J., Vidal-Valverde C., Sotomayor C., Diaz-Pollan C., Urbano G. Influence of processing on available carbohydrate content and antinutritional factors of chickpeas. *Eur Food Res Technol*. 2000; 210(5):340-345. doi:10.1007/s002170050560.
16) Huang S., Liu Y., Zhang W., et al. Composition of legume soaking water and emulsifying properties in gluten-free bread. *Food Sci Technol Int*. 2017; 24(3):232-241. doi:10.1177/1082013217744903.
17) He Y., Shim Y.Y., Mustafa R., Meda V., Reaney M.J.T. Chickpea Cultivar Selection to Produce Aquafaba with Superior Emulsion Properties. *Foods*. 2019; 8(12):685. doi:10.3390/foods8120685.
18) Choya P.F., Combarros-Fuertes P., Camino DA., et al. Study of the technological properties of Pedrosillano chickpea aquafaba and its application in the production of Egg-Free baked meringues. *Foods*. 2023; 12(4):902. doi:10.3390/foods12040902.
19) Aquafaba's Versatility - Today's Dietitian magazine. https://www.todaysdietitian.com/newarchives/0917p36.shtml.
20) Karatay G.G.B., Galvão A.M.M.T., Hubinger M.D. Storage stability of conventional and high internal phase emulsions stabilized solely by Chickpea Aquafaba. *Foods*. 2022; 11(11):1588. doi:10.3390/foods11111588.
21) Echeverria-Jaramillo E., Shin W.S. Current processing methods of aquafaba. *Trends Food Sci Technol*. 2023; 138:441-452. doi:10.1016/j.tifs.2023.06.022.
22) He Y., Shim Y.Y., Shen J., et al. Aquafaba from Korean Soybean II: Physicochemical Properties and Composition Characterized by NMR Analysis. *Foods*. 2021; 10(11):2589. doi:10.3390/foods10112589.
23) Khattab R.Y., Arntfield S.D. Nutritional quality of legume seeds as affected by some physical treatments 2. Antinutritional factors. *LWT- Food Sci Technol*. 2009; 42(6):1113-1118. doi:10.1016/j.lwt.2009.02.004.
24) Kilicli M., Toker O.S. Some physicochemical and technological properties of cooking water of pulses as a canned industry waste: effect of ultrasound treatment during soaking. *Int J Food Eng*. 2022; 18(2):105-118. doi:10.1515/ijfe-2021-0245.

25) Lafarga T., Villaró S., Bobo G., Aguiló-Aguayo I. Optimisation of the pH and boiling conditions needed to obtain improved foaming and emulsifying properties of chickpea aquafaba using a response surface methodology. *Int J Gastron Food Sci*. 2019; 18:100177. doi:10.1016/j.ijgfs.2019.100177.
26) Lawo D, Esau M, Engelbutzeder P, Stevens G. Going Vegan: The Role(s) of ICT in Vegan Practice Transformation. *Sustainability*. 2020; 12(12):5184. doi:10.3390/su12125184.
27) He Y., Purdy S.K., Tse T.J., et al. Standardization of Aquafaba production and application in vegan mayonnaise analogs. *Foods*. 2021; 10(9):1978. doi:10.3390/foods10091978.
28) Serventi L. *Upcycling Legume Water: from wastewater to food ingredients*. 2020. doi:10.1007/978-3-030-42468-8.
29) Muhialdin B., Mohammed N.K., Cheok H.J., Abd-Elaziem F., Hussin A.S.M. Reducing microbial contamination risk and improving physical properties of plant-based mayonnaise produced using chickpea aquafaba. *Int Food Res J*. 2021; 28(3):547-553. doi:10.47836/ifrj.28.3.14.
30) Silva P.G., Kalschne D.L., Salvati D., Bona E., Rodrigues A.C. Aquafaba powder, lentil protein and citric acid as egg replacer in gluten-free cake: A model approach. *Appl Food Res*. 2022; 2(2):100188. doi:10.1016/j.afres.2022.100188.
31) Pedrosa M.M., Cuadrado C., Burbano C., et al. Effect of instant controlled pressure drop on the oligosaccharides, inositol phosphates, trypsin inhibitors and lectins contents of different legumes. *Food Chem*. 2012; 131(3):862-868. doi:10.1016/j.foodchem.2011.09.061.
32) Shim Y.Y., He Y., Kim J.H., et al. Aquafaba from Korean Soybean I: A Functional Vegan Food Additive. *Foods*. 2021; 10(10):2433. doi:10.3390/foods10102433.
33) Saget S., Costa M., Styles D., Williams M. Does Circular Reuse of Chickpea Cooking Water to Produce Vegan Mayonnaise Reduce Environmental Impact Compared with Egg Mayonnaise? *Sustainability*. 2021; 13(9):4726. doi:10.3390/su13094726.
34) Suna S, Çopur ÖU. A new approach: replacement and alternative foods for food industry. In: *Elsevier eBooks*. ; 2018:1-30. doi:10.1016/b978-0-12-811446-9.00001-0.
35) Singh N. Pulses: an overview. *J Food Sci Technol*. 2017; 54(4):853-857. doi:10.1007/s13197-017-2537-4.
36) Stantiall S.E., Dale K.J., Calizo F.S., Serventi L. Application of pulses cooking water as functional ingredients: the foaming and gelling abilities. *Eur Food Res Technol*. 2017; 244(1):97-104. doi:10.1007/s00217-017-2943-x.
37) Raikos V., Hayes H., Ni H. Aquafaba from commercially canned chickpeas as potential egg replacer for the development of vegan mayonnaise: recipe optimisation and storage stability. *International J Food Sci Technol*. 2019; 55(5):1935-1942. doi:10.1111/ijfs.14427.
38) El-Adawy T.A. Nutritional composition and antinutritional factors of chickpeas (Cicer arietinum L.) undergoing different cooking methods and germination. *Plant Foods Hum Nutr*. 2002; 57(1):83-97. doi:10.1023/a:1013189620528.
39) Yazici G.N., Taspinar T., Ozer M.S. Aquafaba: A Multifunctional Ingredient in Food Production. *Biol Life Sci Forum*. 2022. doi:10.3390/foods2022-13004.
40) Mustafa R., He Y., Shim Y.Y., Reaney M.J.T. Aquafaba, wastewater from chickpea canning, functions as an egg replacer in sponge cake. *Int J Food Sci Technol*. 2018; 53(10):2247-2255. doi:10.1111/ijfs.13813.
41) International Day of Awareness of Food Loss and Waste 2022. UNEP - UN Environment Programme. https://www.unep.org/events/un-day/international-day-awareness-food-loss-and-waste-2022.
42) Tufaro D., Cappa C. Chickpea cooking water (Aquafaba): Technological properties and application in a model confectionery product. *Food Hydrocoll*. 2023; 136:108231. doi:10.1016/j.foodhyd.2022.108231.
43) Xu B., Chang S.K.C. Phytochemical profiles and Health-Promoting effects of Cool-Season food legumes as influenced by thermal processing. *J Agric Food Chem*. 2009; 57(22):10718-10731. doi:10.1021/jf902594m.
44) Pereira R.N., Rodrigues R., Avelar Z., et al. Electrical fields in the processing of Protein-Based foods. *Foods*. 2024; 13(4):577. doi:10.3390/foods13040577.
45) Wei L., Ge T., Zhao J., Wang L., Jiang J. Evaluation of mung bean protein and aquafaba as co-stabilizer for sour aerated emulsions. *Food Hydrocoll*. 2024; 146:109196. doi:10.1016/j.foodhyd.2023.109196.
46) Stasiak J., Stasiak D.M., Libera J. The potential of Aquafaba as a Structure-Shaping additive in Plant-Derived food technology. *Appl Sci*. 2023; 13(7):4122. doi:10.3390/app13074122.
47) Hwang S, Yu J, Shin W. Physicochemical and sensory properties of vegan ice cream using upcycled Aquasoya powder. *Int J Food Sci Technol*. 2024; 59(9):6431-6442. doi:10.1111/ijfs.17388.
48) Shukla D., Tewari B.N., Trivedi S.P., Dwivedi S., Kumar V., Tiwari V. Quality and functional attributes of muffins with incorporation of fruit, vegetable, and grain substitutes: A review. *J Appl Nat Sci*. 2024; 16(1):344-355. doi:10.31018/jans.v16i1.5330.
49) Ronie M.E., Aziz A.H.A., Kobun R., et al. Unveiling the potential applications of plant by-products in food – A review. *Waste Manag Bull*. 2024; 2(3):183-203. doi:10.1016/j.wmb.2024.07.008.