REVIEW ARTICLE

Aquafaba: Nutritional Significance for Vegans. A Way towards Environmental Sustainability

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ABSTRACT

Chickpea also known as “garbanzo bean” is a versatile legume, consumed all over the world. Other than being consumed as a whole legume, chickpeas and other legumes are mostly commercialized in brine or sugar solution. This solution more commonly known as aquafaba can form stabilized emulsions owing to its unique characteristics and composition. The aim of this review is to give an overview of the nutritional and functional properties of aquafaba along with its environmental sustainability. This wastewater is an opulent source of proteins, carbohydrates (insoluble & soluble), minerals and other bioactive substances especially, tannins, saponins, phenolic compounds and oligosaccharides. Over the past years the food industry has shown increased interest in product properties and functions. Studies done in this regard suggested its utilization in various bakery products like cakes, cakes, mousse, meringues, and vegan-based mayonnaise. While using it may be a great alternative for vegans and people with egg allergies but research regarding its use and environmental sustainability is needed before further large-scale production of these products is conducted.

Keywords: *Aquafaba, Chickpeas, Egg Allergies, Environmental Sustainability, Vegan Food Products.*

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Introduction

The devastation caused by recent catastrophes both natural and manmade, like the global pandemic, recent floods, and food insecurity should be a call to action for considering alternative solutions for finding a sustainable way forward.[1] Products of animal origin, livestock and poultry industry have been around for several decades.[2] In present times consumers are increasingly aware of the ethical, and environmental concerns of an animal-based diet.[3] Making the food industry pivot towards creating new plant-based products to meet increasing consumer demands.[4] Considering the above-mentioned facts, canned chickpea is increasingly being studied for plant based product development owing to their unique properties.[5]

Chickpea (Cicer arietinum L.), also called garbanzo bean is an age-old pulse and an edible seed characterized as a legume.[6] Because of its nut-like taste and diverse sensory application in foods, it has traditionally been included in various culinary recipes.[7] The origin of chickpea could be drawn back to Middle East, rather "The Fertile Crescent" thousands of years back.[8] Today, it is utilized all around the world and is a healthful source of protein, fat, fiber, and carbohydrates.[9] Chickpeas are divided into two varieties, the light seeded Kabuli and the smaller dark desi type.[10] Pulses differ from other plant foods, as they possess a higher protein quantity (17%–30% dry weight). The primary proteins present in chickpeas and pulses are albumin and globulin, with trace amounts of glutalins and prolamins.[11] They can be a nutritious protein source for all consumers, especially for vegans and people searching for environmentally sustainable food substitutes. Primarily, because of their economic viability and nutritional composition. Traditional soaking and boiling are not the only methods used to improve the quality of legumes. A variety of processing methods like canning and roasting are also used.[12] Canning chickpeas in viscous solution or brine is a widespread practice in the food industry. Foams and emulsions can be formed with this solution, which can conveniently be utilized as a thinking element. Various scientific claims have been made about

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aquafaba's potential to be an effective substitute for eggs and milk protein. Therefore, Aquafaba, a byproduct solution that can be utilized as a plant-based emulsifier, is produced by preserving or boiling pulse seeds into water.[13] It can also be used to substitute eggs in sauces, patisserie, and bakery items.[14] Aquafaba is made up of 92–95% water and 5–8% dry matter, including carbohydrates (such as sugars, insoluble & soluble fiber), lower molecular weight proteins (0.95–1.5 percent w/v;24kDa), saponins, & few Maillard Reacting products.[15]

Considering the above-mentioned facts, a plant-based product made using aquafaba would be the next groundbreaking invention to combat the adverse effects of livestock on climate change. As prior research has shown that livestock is accountable for about 14.5% of anthropogenic greenhouse gas (GHG) emissions.[16] Furthermore, livestock production has a detrimental impact on depleting fresh water, loss of biodiversity, distress of fauna and antibiotic resistivity, to name a few.[17] However, the replacement of eggs is a big concern, in addition to being a valuable food source. They are most commonly used in diet as well as in bakery industry to form emulsions, gels, enhance color, and flavor at the same time.[18] Plant alternatives like aquafaba from canned chickpeas can have numerous benefits. They have the potential to alleviate animal suffering, environmental damage, and public health risks. Therefore, the main objective of this review is to provide an overview of the nutritional and functional properties of aquafaba & determine if it can be a viable vegan alternative with a low carbon footprint. (Figure 1)

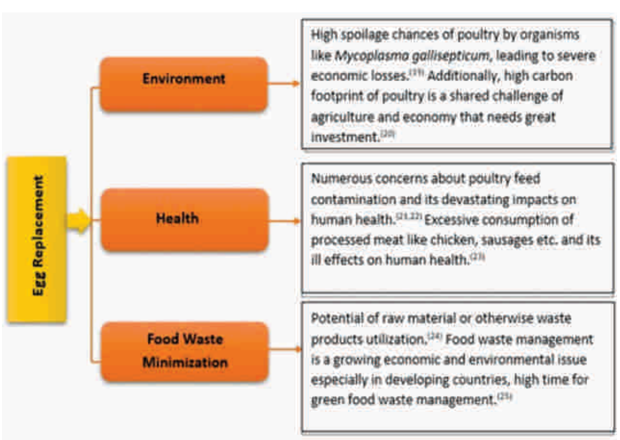

Fig 1: Rational behind the need for egg replacement in food

1. Aquafaba Composition

Aquafaba's composition depends on the kind of pulse used, structure of the pulse, as well as cooking procedure. During the processing of dry beans, a complex mix of components is suggested to get transferred to the canned water.[26] The legume comprises two cotyledons, parted from the embryonic center, forming 80-90% of the seed. Followed by a cell wall comprising 8-18% of the seed.[27] The bulk of the nutrients in the bean is found in the cotyledon, which is closely packed with starch granules and coated into protein matrices, even containing smaller protein granules.[28] The composition and strength of cell wall layer is reduced by soaking of legumes followed by heat treatment. Carbohydrates contained in the cell wall could be depolymerized or solubilized and are therefore transferred into the cooking water.[29] Protein (0.5-1.72g/100g), soluble (0.04-1.66g/100 g) & insoluble (0.93-2.4g/100g) carbohydrates, ash (0.4-0.78 g/100g), saponin (4.5-14mg/g), and phenolic compounds (0.3-0.7mg/g) make up the majority of dry matter in the resulting mixture (aquafaba).[30]

a. Proteins

Vegetarian protein, allergen-free diets, and low-carbon food sources have become more popular among consumers. Because these foods are rich in protein, fiber & low in saturated fat, their importance is ever increasing especially of chickpeas.[31] Protein solubilization in the solution (aquafaba) is aided by the breakdown of the bean hulls during processing.[32] The albumin 2S group is thought to account for a large number of aquafaba proteins, followed by oligomeric protein vicilin 7S & legume 11S.[33] Protein content ranges from 18-29% in dry matter of chickpea aquafaba, 29% in split yellow peas, 32% in green lentils, & 12% in yellow soybeans.[34] A varied range of protein content is reported in some cases. Mainly because of difference in variety of the legumes. While the quantity of soluble proteins in cooking water can vary according to the size of legume. Smaller seeds tend to have a higher protein content.[35]

b. Carbohydrates

Carbohydrates may be classified into two types: insoluble & soluble. Soluble carbohydrates account for 0.8-24% of chickpea aquafaba dry matter, while insoluble carbohydrates account for 47% of dry matter of chickpea cooking water.[36] Bulk of water solubilized carbohydrates are lower molecular weight (LMW) sugars. Composed of 40% disaccharides, primarily sucrose & 60% α-galactosidase like stachyose & raffinose.[37] While insoluble carbohydrates like starch make up the dietary fiber. Commonly known as the edible component of plants that is not digested and absorbed into the small intestine which eventually enters colon & is subjected to fermentation by intestinal bacteria.[38] Although, starch is a primary constituent of beans, it is not present in aquafaba. Studies conducted in this regard, of granule iodine test for starch suggested a negative or insignificant result, as it forms big granules of interwoven chains and is resistant to heat processes.[39]

c. Fat and Mineral Content

As most legumes are generally low in lipid levels, the fat constitute of aquafaba is particularly lower that it cannot be identified in quantifiable quantities.[40] In one of the recent studies fat content was reported to be (0.14 ± 0.01), which is in accordance with previous findings.[41] Similarly, another study suggested a value of <0.1%.[42] Upon heat processing of pulses especially chickpeas, a significant loss of small fractions of fat occurs. That can be due to either, leaching out of nutrients into cooking water, or degradation of fat during processing.[43] Contrary to the above mentioned findings, one study reported a high fat content of 2.2%.[44]

d. Other Bioactive Substances

Most legumes are a rich source of plant metabolites and nonnutritive bioactive chemicals, including tannins, saponins, phenolic compounds, phytic acid, and oligosaccharides. Although, some of these constitutes may possess a negative effect as they can act as anti-nutritive substances hindering digestibility, digestive enzyme activity, nutrient balance and health.[45] For instance, oligosaccharides like raffinose, can be responsible for undesirable gastrointestinal indications like diarrhea, flatulence, and stomach discomfort. As human digestive system lacks the enzyme α-galactosidase for proper digestion.[46] Thereby, solubilizing such constituents via soaking legumes may help reduce their concentration. Furthermore, heat-sensitive bioactive compounds like saponin, phenolic compounds, and phytic acids which are recognized thermolabile components, may be inactivated by subsequent treatment at higher pressure and temperature.[47] As a result, the concentration of these antinutritional components in aquafaba is substantially lowered. Consequently, imposing fewer adverse effects.[48] (Table 1).

Table 1: Aquafaba Nutritional and Physical Properties

Nutritional Composition	**Chickpeas (Unit)**
Carbohydrates	2.9%
Protein	1.0%
Fats	0.2%
Dietary fiber	ND[1]%
Calcium	7.3 mg/100g
Sugars	1.3%
Sodium	3.2 mg/100g
Physical Properties	
PH	3.5-6.5
Viscosity	5.7-114.2 (mPa·s)[2]
Density	1.020 (g/mL)
Water absorption capacity	1.46 (g/g)
Oli absorption capacity	3.22 (g/g)

2. Aquafaba Uses

Over the past years, many culinary recipes have been developed that utilize aquafaba to minimize the usage of eggs. There are also renowned books containing a compilation of recipes that utilize aquafaba.[49–50] Owing to its unique chemical composition of proteins, carbohydrates, polysaccharides, saponins and phenolic compounds. Allows this humble wastewater to perform varied functional roles like emulsification, foaming and gelling, in various vegan formulations.[51] Below are some of the uses of aquafaba.

a. Mayonnaise

Over the past years, a vast majority of individuals globally have shifted towards more sustained and healthful vegan diets. Considering that, vegan mayonnaise made using chickpea waste water could be used as an eggless anti-allergic alternative to full-fat traditional mayonnaise.[52] Mayonnaise is primarily a semi-solid oil in water suspension. Traditionally, it is synthesized by combining vegetable oil, egg yolk, vinegar, & seasonings. Conventional everyday use mayonnaise products are vulnerable to degradation because of oxidizing of unsaturated fats into its oil at room temperature. As a result, the nutritional value of fat-based mayonnaise is compromised due to losses of polyunsaturated fats and vitamins, that otherwise would have been beneficial to health. In most cases oxidative process impairs the nutritional value of fat-based products. Thus, removing intrinsic (prooxidant content), and extrinsic (high temperature and light) in addition to adding high quality antioxidants, can potentially suppress oxidative stress and also increase the shelf life of mayonnaise.[53] Numerous studies have shown that aquafaba can be utilized as an alternative of egg yolk for mayonnaise production owing to its emulsifying and stabilizing qualities. Specifically, chickpea aquafaba is a viable alternative emulsifier with excellent radical scavenging properties for making egg free vegan emulsions.[54] Consumer acceptability and sensory assessment of vegan mayonnaise revealed no substantial variations in odor, consistency, and flavor. It just portrayed variation in color: aquafaba mayonnaise had a stronger color concentration compared to egg mayonnaise.[55] There are various brands of commercial vegan mayonnaise sold all over the world. Some of the most renowned include, Vegan Mayonnaise by Veggie-Vegan Naise's Mayo Classic, Rubies in the Rubble's Aquafaba Mayo, and Chosen Foods' Classic Vegan Mayo.[56] Despite providing a humane and healthier alternative for vegans. There are still some studies that suggest contradictory findings to the above mentioned. The major concern presented is on reducing environmental foot printing. Because of higher power supply usage in the processing of aquafaba. Replacing egg yolk by aquafaba for mayonnaise might have greater ecological impacts like climate change. Thus, the cyclical reuse of chickpea water may not necessarily have a lesser environment protective effect, although potentially gives a more healthful alternative.[57]

b. Cakes

Aquafaba is a great alternative for whole eggs or egg white in bakery products especially cakes, owing to its unique chemical composition.[58] Past studies comparing cakes made with whole eggs and aquafaba found that substituting egg white with aquafaba had a negligible effect on the physicochemical properties of sponge cake. Aquafaba cake contained little moisture, had less height, and had a lower PH. It was also heavier than the egg white cake.[59] Because of these drawbacks, some studies recommend just substituting up to 50% of eggs with aquafaba, as it gives higher uniformity.[60] The color analysis revealed the crust of an aquafaba cake to be of a much deeper color because of Millard's reaction (caramelization) amongst aquafaba proteins & simple sugars.[61]

c. Mousse

Because of the frothing and emulsifying capabilities of aquafaba, it has an immense potential to mimic whipped cream and mousses. Previous studies suggest no substantial variances of appearances (color & texture), odor or taste in animal or plant based products.[62] Although, there are no significant variations in taste between egg white mousse and aquafaba mousse. Calcium, sodium, and saponins in beans may contribute to a slight bitterness and salty flavor in the end product.[63] Additionally, egg white foam is said to be much more stabilized due to the smaller size of the foam particles and thicker membrane.[64]

d. Meringue

The meringues made using aquafaba have the same palatability and color as egg white meringue. It does, however have considerable variances in rigidity & constancy that is less in comparison to other animal products.[65] Research confirmed the impacts of higher concentration ultrasound on the foam & emulsification capabilities of chickpea cooking water (aquafaba). Results suggested that sensory qualities (taste, consistency, color), & emulsification activities of meringue improved in comparison with untreated

Table 2: Studies showing the application of aquafaba in the food industry

Food Product	Country/ Brands Availability	Use/ Benefit
Mayonnaise	Australia, Europe, United State	Egg Allergies, Vegans, Sensory Properties
Cake/ Cupcakes	United Kingdom, Korea	Sensory and Physiochemical Properties
Mousse	United Kingdom, Australia	Egg Allergies, Vegans, Similarity in Texture
Meringue	United States	Egg Allergies, Vegans, Texture

aquafaba meringue. It also improved hardness, consistency, and adhesiveness.[66] Meringue Powder by Meringue shop has commercially manufactured aquafaba-based meringue powders to enable their creation and utilization.[67] (Table 2)

3. Environmental Impact

Even though aquafaba is a viable alternative for animal products and people with egg allergies. And the idea of food waste minimization is indeed a sustainable approach. But in-depth market research needs to be conducted with an environmental impact analysis of this substitute. Despite its wide range of applications, research on the environmental effects of mayonnaise manufacturing found, egg-based mayonnaise to be more environmentally friendly than aquafaba-based product.[68] Aquafaba products can be made more sustainable if renewable energy resources are employed in processing legumes.[69] However, there is still a plethora of studies conducted in the past suggesting the benefits of switching to a plant-based diet exceed its risks. There is a multitude of advantages linked to following a plant-based diet most importantly, a lowered risk of acquiring chronic diseases like CVDs, diabetes, obesity, and thyroid problems. In addition to satisfaction, increased wellbeing, ethical and environmental benefits.[70] Thus, the above findings suggest that the cyclic reuse of aquafaba may not drive lower environmental impact, despite being a healthful and nutritious alternative for vegans and people with egg allergies.

Conclusion

Chickpea is a versatile legume consumed all over the world. Canned chickpea brine solution also known as aquafaba has gained popularity over the past years, it is known to form stable emulsions. This wastewater is a decent source of protein, soluble & insoluble carbohydrates, and bioactive compounds like tannins, saponins, phenolic compounds and oligosaccharides. Most of which are heat sensitive and reduced during processing. Due to these properties, it has been used in a vast majority of products like vegan mayonnaise, cakes, mousse, and meringues. Although, it is a great alternative for vegans and people with egg allergies. Further studies regarding the environmental sustainability of these products are required to validate previous findings.

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