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Athira Dileep
Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Chinju Baby
Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Gopika B
Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author
Athira Dileep
Department of Food Technology and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Studies on the functional properties of legume and pulse cooking water

Athira Dileep, Chinju Baby and Gopika B

Abstract
The ability of pulse cooking water derived from chickpea, cowpea, and horse gram to serve as an ingredient in food systems was studied, and the characteristics of the cowpea cooking water were found to be comparable to aquafaba. Therefore, the optimization of cowpea cooking water based on the effect of change in level of pH by pH 3, pH 4.5, pH 6, pH 7, pH 8.5 on the functional properties were analysed and the best results were obtained at pH 6. Moreover, the cowpea cooking water at pH 6 was proceeded to drying and the powdered form was subjected to sensorial and functional studies revealed that there is a reduction of functional qualities upon conversion from liquid to powder. However, there is growing interest in commercial production of cowpea cooking water, although, more effort is needed to understand conditions that affect its functionality and to establish approaches for standardizing commercial production.

Keywords: By-products, cooking water, egg- replacer, emulsifier, foaming agent

Introduction
Urbanization causes food security and waste management issues for both humans and the environment (FAO, 2018) [15]. In this context, the efficient use of by-products, residues, and wastes created by agro-industrial and food processing opens the door to a wide range of benefits. Canning or cooking pulse seed in water produces a solution that, when separated from the seed, can be used as a plant-based rheological ingredient in food compositions (Stantiall *et al*., 2018) [51]. This solution, known as "aquafaba," has become a popular cuisine ingredient that has been widely covered and trending on social and professional media. It is especially popular among posters who showcase vegetarian and vegan recipes (Aguilera *et al*., 2009) [2].

The discovery of the functional properties of the legume/pulse cooking water as egg replacer has generated wide interested in the application as food ingredient. The dry matter accounts for 3–6 g/100 g of the liquids, mainly consisting of carbohydrates: sugars, soluble and insoluble fibre. Proteins and minerals represents 10-30% of the dry matter (He *et al*., 2021) [19]. Studying the effect of protein is useful because the quality of many food formulations such as foam and emulsion creation and their stability are dependent on the properties of protein. Examples include formation of good whipped toppings and desserts, water binding capacity to entrap water in bread and ice creams and oil binding applied in doughnuts and other desserts and emulsification to form/stabilize fat emulsions in soups and cakes (Shim *et al*., 2018) [48].

Horse gram is a pulse crop that is underutilized and may be cultivated in a variety of unfavourable environmental conditions. With an abundance of protein, minerals, and vitamins, it plays a significant role in human nutrition. Due to the presence of non-nutritive bioactive compounds, it has been associated to a lower risk of developing a number of diseases in addition to its nutritional value. These bioactive compounds, such as fiber, enzymatic/proteinase inhibitors, phytic acid, and phenolic acid, have important physiological and/or metabolic impacts. Horse gram was used in traditional medicine to give treatment to ailments such as kidney stones, urinary diseases, piles, common cold, throat infection, and fever (Bhartiya *et al*., 2015) [6]. In various researches, mucilaginous polysaccharide and protein was isolated from pre-treated cowpea which indicate their likelihood to be used as an emulsifying agent in food systems (Khalid *et al*., 2015) [25]. High levels of iron, potassium, magnesium, molybdenum and other minerals are found. Similarly, nutritionally relevant levels of saponins (5-15 mg/g) and phenolic compounds (0.2-0.7 mg/g) leaches in the cooking water. A 100 ml serve of these ingredients could meet the RDA intake of numerous nutrients. Interestingly, the levels of antinutritive phytic acid and trypsin inhibitors are found to be low

in several studies, possibly due to thermal degradation (Alsalman *et al*., 2020) [3].

Fascinatingly, it was observed that the nutritional profile of the cooking water did not correspond with legumes composition. Instead, seeds geometry determined cooking water profiles. For example, chickpeas uneven shape allowed the outer shell to break upon boiling, thus releasing more insoluble fibre than other legumes. Seed conformity, size and thickness influence solid release in the processing water, resulting it a new nutritionally interesting food ingredient (Thakur *et al*., 2019) [53].

Legume/pulse cooking water was revealed to replace egg white in confectionery products. Thus, recently several studies investigated legume cooking water as texturizer. Most samples were slightly acidic (pH 6.1-6.5). Foaming capacity ranged from 38-97% based on legume type, encircling egg white solutions of similar concentration. A direct correlation to protein content was found. In spite of the boiling process, most protein was soluble (86-100%). Ultrasounds treatments enhanced foaming properties of cooking water (Meurer *et al*., 2020) [36]. All foams were very stable, potentially owing to saponins. Emulsifying properties are found outstanding, reaching values of 47 m^2/g (lentils) and 100% (chickpeas). An amalgamation of fibre, protein and saponins potentially contributed to highly stable emulsions. A higher hydrophobicity was observed, with absorption capacity of oil exceeding that of water (2.70–3.20 vs. 0.10–2.20 g/g) due to the presence of more hydrophobic sites on macromolecules. Finally, excellent prebiotic potential was determined (Serventi *et al*., 2020) [45]. Most cooking water contained considerable levels of fermentable oligosaccharides, protein and minerals to aid bacterial growth and the only exception was soy, may be due to the higher phytate content. Concisely, pulses cooking water are good foaming and gelling agents and excellent emulsifiers (Alsalman *et al*., 2020) [3].

The legume/pulse cooking water gained popularity as vegan alternative to eggs in 2015. From that discovery, multiple food applications have been put forward. Raw foams were developed by replacing egg white with aquafaba, despite the fact that softer texture and darker colour were observed. When cream was introduced, sensory acceptability was high, with inferior perceived sweetness, likely the result of phenolics and saponins. Baking into meringues draw attention to the need for gelling abilities, present only in the cooking water of certain pulses (He *et al*., 2021) [19]. Lower saponin content and lighter colour of chickpeas and peas let them to be acceptable replacements of egg white in meringues. Alternatively, gluten-free crackers were manufactured from soy cooking water. Impressively, hardness decreased during storage, while moisture content increased (He *et al*., 2021) [19]. The high hydrophilicity of soy proteins was observed to be responsible of the antistaling mechanism. In leavened products such as gluten-free bread, chickpea cooking water notably enhanced loaf volume and reduced crumb hardness (Serventi *et al*., 2020) [45]. Superior structural stability and pores homogeneity was represented by microscopy, equivalently to the hydrocolloid xanthan gum. Finally, the pulse/legume cooking water was tested in cakes and mayonnaise to replace whole eggs. Insignificant differences in colour were noted and satisfying sensory acceptance was achieved (Mustafa *et al*., 2020) [38]. Legume cooking water can ascertain applications as egg replacers and hydrocolloids.

Nearly all studies on the functionality of pulse/legume cooking water has employed chickpea as the key component as it is widely used and available easily. Hardly any other pulse or legumes was taken for the analysis and this bring about a need to explore more of them. Thus, this study is designed to work on cooking water obtained from horse gram and cowpea aside chickpea. The study will emphasize on the composition and physiochemical features of the samples and the application in food systems based on their functionality. There is also a need to convert the cooking water into a more fitting state for its convenient use therefore the study also deals on advancing the drying conditions for the development of its power form along with its functionalities.

Materials and Methods

Sample preparation and Setup

Chickpeas, cowpeas and horse gram were soaked in water for 16 hours for optimizing the pulse hydration and then placed in a classic pressure cooker (Hawkins Inc.) with 1:4 pulse- water ratio and cooked for 60 minutes as determined by a preliminary study (Meurer *et al*., 2020) [36]. After cooking, the pulse cooking water was drained out from the cooked pulse using a muslin cloth and used for analysis. All the test samples were analysed in triplicate for various output parameters except when stated otherwise.

The effect of changes in the pH of cowpea cooking water was measured by establishment of fixed and variable set points. The pH 6.8 as measured directly in the sample, were chosen as the reference condition in the further tests of effects of pH. The pH range included test of pH 3, pH 4.5, pH 6, pH 7, and pH 8.5. The pulse cooking water was adjusted with 2% citric acid and/or 0.1N NaOH to reach the targeted pH-values, respectively, and recorded at a pH meter (Labman, India).

Compositional analysis

Protein: Kjeldahl method was used to estimate the protein content of three pulse cooking water. Protein (%) from chickpea, cowpea and horse gram cooking water was analyzed from 5ml of each sample using a kjeldahl machine (Pelican Inc, Kjeloplus- Kjelodist EAS VA).

Moisture: Moisture contents of pulse cooking water by heating samples at 100 ± 2 °C for 16-18 hrs in a drying oven (Ratanapariyanuch *et al*., 2012) [41].

Physiochemical analysis

pH: Pulse cooking water and analogue pH values were measured using a portable food and dairy pH meter.

Microscopic visualization of bubbles: The samples were whisked by using a hand blender with optimum speed for 2 min. The bubbles were observed under a microscope at 10X.

Functional analysis

Foaming Capacity and Stability: Foaming capacity of aquafaba was measured using the procedure detailed in Shim *et al*. (2018) [48]. For this, 100 ml of aquafaba solution was placed in a graduated cylinder and whipped using a hand blender with fixed speed for 2 min. Foaming capacity was expressed in percentage by using the Eq. (1):

$$FE\% = Vf_0/Vl_i \times 100 \quad (1)$$

Where Vf_0 is the foam at time T_0 and Vl_i is the initial volume of sample, respectively.

Foam stability of aquafaba was measured by allowing the

foam to stand in the graduated cylinder over time that was recorded as the bubbles broke down and the level decreased using the latter Eq. (2).

$$FS\% = (Vl_i - Vl_t / Vl_i - Vl_0) \times 100 \quad (2)$$

Where, Vl_0 is the liquid volume at time 0, Vl_t is the liquid volume after time t and Vl_i is the initial volume of sample.

Emulsion Capacity and Stability: Emulsion capacity (EC) of aquafaba was determined by the method detailed in Alsalman *et al*. (2020) [3] with some modifications. Briefly, pulse cooking water samples were diluted 1:8 using distilled water and homogenized for 1 min at 740 rpm using a magnetic stirrer. To 5 ml homogenized sample, 5 ml canola oil was added and homogenized again for 2 min, which was followed by centrifugation at 3,000 rpm for 30 min. The supernatant (oil) was separated, and the emulsion formed was measured by a pipette. Emulsion stability was measured according to the method detailed in the latter paper. The same emulsion formed, as detailed earlier, was warmed in a water bath at 80 ^{0}C for 30 min, cooled to room temperature, centrifuged at 3,000 rpm for 30 min, and the volume of emulsion was measured again as described previously. EC was calculated using the Eq. (3):

$$EC\% = H_2\ (ml)/H_1\ (ml) \times 100 \quad (3)$$

Where H_1 is the initial height of the solution before emulsification and H_2 is the height of the emulsified layer.
To determine the emulsion stability (ES), the previously generated emulsions were heated at 85 °C for 10 min, cooled at room temperature for 5 min, and further centrifuged at 14,000 rpm for 2 min. ES was expressed as the percentage of emulsion remaining after centrifugation as determined by Garcia-Vaquero *et al*. (2017). ES was calculated by the Eq. (4):

$$ES\% = H_3\ (ml)/H_1\ (ml) \times 100 \quad (4)$$

Where, H_3 is the height of emulsified layer recorded and H1 is the initial height of solution before emulsifying.

Total phenolic content (TPC): Total phenolic content (TPC) of the pulse cooking water was measured with a visible spectrometric analysis by Damian *et al* (2018) [11] combining 2.5 ml of 0.2 N FC (Folin-Ciocalteu) reagent with 2.0 ml of 7.5% sodium carbonate, 0.4 ml of water and 0.1 ml of pulse cooking water sample. Sample aliquot was reduced from 0.5 to 0.1 ml to obtain a linear response. Gallic acid was used as a standard. Samples were incubated at room temperature for 2 h in a dark place and then absorbance was read at 760 nm on a spectrophotometer. Total phenolic content was expressed in mg of gallic acid equivalents (GAE) per mL using a standard curve (Fig 1).

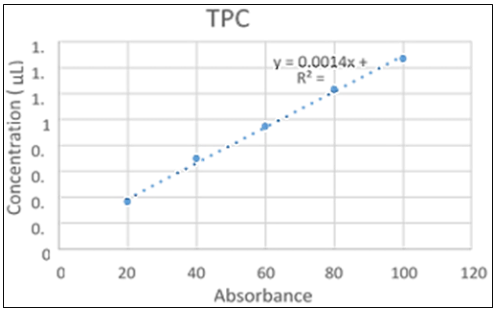


Fig 1: Standard curve of TPC Assay

Total Flavonoid Content (TFC): The TFC of the sample was measured by the aluminium chloride spectrometric assay method described by Kim, Jeong, and Lee (2003) [26] by reading the absorbance at 510 nm. The sample is diluted and added with sodium nitrite and aluminium chloride, followed by sodium hydroxide. Total flavonoid content of liquid sample was expressed as mg of quercetin equivalent (CE) per ml of sample using a standard curve (Fig 2).

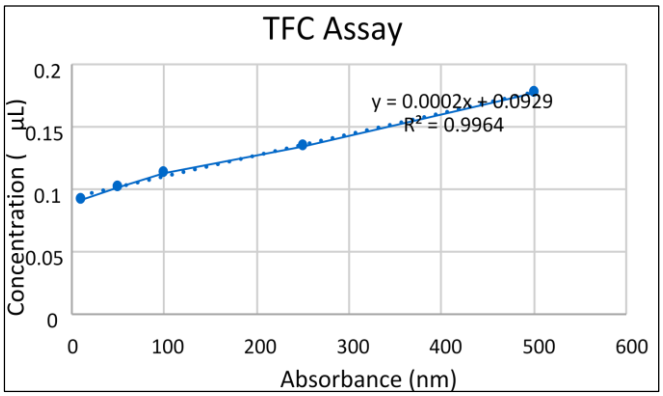


Fig 2: Standard curve of TFC Assay

Antioxidant properties: Free radical scavenging capacities of the phenolics from pulse cooking water were determined by reaction with the DPPH radical, according to the method adapted from Sreerama *et al*. (2012) [50]. The absorbance was measured at 517 nm using a spectrophotometer. Decreasing absorbance of the DPPH solution indicates an increase in DPPH radical scavenging activity. The radical scavenging activity was expressed in terms of IC50 (concentration in lg required for a 50% decrease in absorbance of DPPH radical), calculated at 517 nm. A plot of absorbance vs concentration was made to establish the standard curve and calculate IC50 values. DPPH was used as positive controls at 100 g/ml concentration. Data are reported as means ± SD for three replications.
Cooking water of cowpea was made into pH 3, pH 4.5, pH 6, pH 7, pH 8.5 from the original pH 6.76 ± 0.05 by 2% citric acid and/or 0.1N NaOH. Foaming capacity and stability, emulsion capacity and stability, and microscopic examination was analysed by the above mentioned method, respectively.
The sample solution showed best result at pH 6 and was subjected to drying by a combination of vacuum oven followed by tray drying.

Drying: The sample solution of cowpea cooking water with pH 6 was poured into a petriplate based with aluminium foil for better and efficient drying and easiness in collecting the sample. The conditions maintained for drying of the samples are specified in the Table 1. After drying the samples were carefully scrapped out and weighed.

Table 1: Drying Methods and Parameters

Drying method	Temperature (ºC)	Time (hrs)
Vacuum Oven	80	4
Tray Drier	40	4

Yield: The amount of PCW obtained, which was expressed as grams of PCW per 100 grams of chickpeas, was calculated using the amount of PCW obtained after cooking and the amount of pulse before cooking based on Alsalman *et al*. (2020) [3] given Eq. (5).

Yield = Quantity of PCW (g)/Quantity of raw pulse (g) × 100 (5)

Fat Absorption Index: Fat aborption index was conducted based on the procedure followed by Ishara *et al*. (2018) [23]. 0.3g of sample was mixed with refined vegetable oil in a pre-weighed 15mL graduated centrifuge tube for 1min. The supernatant was removed after centrifugation at 2060 rpm for 30 min, and the tubes were then weighed again. FAI was calculated by the Eq. (6)

FAC % = Wt. of sample (g) +oil/Wt. of sample (g) × 100 (6)

Foaming Capacity and Stability: With minor modifications, the procedure stated by Ishara *et al*. (2018) [23] was used to evaluate foaming capacity and stability. 2gm of each sample was added to 50mL distilled water in a 100mL beaker. The suspension was mixed and whipped using a hand blender with fixed speed for 2 min to foam. The volume of foam at 30 seconds after whipping was expressed as foaming capacity and is expressed by the following Eq. (7).

$FC\ \% = V_2\ (mL) - V_1\ (mL)/V_1\ (mL) \times 100$ (7)

Where V1 is the original volume of sample and V2 is the volume of foam after whipping.
The volume of foam, V_3, was recorded one hour after whipping to determine the foaming stability as a percentage of initial foam volume by Eq. (8).

$FS\ \% = V_3\ (Ml) - V_1\ (mL)/V_1\ (mL) \times 100$ (8)

Emulsifying Activity & Stability: Based on the procedure directed by Ishara *et al*. (2018) [23] 1g sample was mixed with 10 mL distilled water and homogenized using a magnetic stirrer at 740 rpm for 1 min. Then it is added with 5 mL refined vegetable oil, the resulting emulsion was centrifuged for 5 min at 1100 rpm. The height of the emulsified layer was measured and the emulsifying activity was calculated as the percentage increase in the height of the solution by the following Eq. (9)

$EA\ \% = H_2\ (mL)/\ H_1\ (mL) \times 100$ (9)

Where, H_1 is the initial height of solution before emulsification and H_2 is the height of emulsified layer.
To evaluate stability of the emulsion, the samples were subjected to temperature cycles of 85±3 °C for 15min in the water bath and the latter was left at an ambient temperature of 27°C for 30 minutes. The height of the formed emulsified layer was then recorded (H3) and the stability of the emulsion was calculated using the Eq. (10) given below.

$ES\ \% = H_3\ (mL)/\ H_1\ (mL) \times 100$ (10)

Where H_3 is the height of the layer after undergoing temperature cycle.

Swelling capacity (SC): The procedure followed was based on Ishara *et al*. (2018) [23]. 2g of the sample was taken in a 50mL measuring cylinder. 30mL of water was added and mixed until homogeneity is reached. The mixture was then left to settle for 24 hours and the final volume (V) occupied by the sample was measured by Eq. (11).

SC = V (mL)/ Sample weight (g) (11)

Water Absorption Index (WAI): The WAI analysis was conducted based on the procedure stated by Sharma *et al*. (2015) [46] and was performed in triplicates. Each 3.0g sample was dispersed in 30mL of distilled water and stirred using a magnetic stirrer for few minutes. This dispersion was allowed to stand for 30min in a water bath at 30°C. Subsequently, the dispersion was centrifuged at 4500 rpm for 10 min. The following Eq. (12) gives the measure of water absorption by the sample.

WAI (g/g) = Wt. of hydrated residue/Wt. of dry sample (12)

Statistical analysis
Data analysis Means and standard deviations for all data were calculated with Microsoft excel 2013. The statistical analysis was performed by the statistical software, SPSS. A minimum of 95%-level (p<0.05) was considered as statistically significant with a 0.95% confidence interval and normal distribution of the data were ensured prior to the statistical analysis. Oneway analysis (ANOVA) was applied for set-ups, which included one variable (pH). The Duncan's honest significant difference (HSD) test was used to determine statistically significant differences between means. Analyses were performed on 3 different samples of pulse cooking water. Results in tables express means and standard deviation. Data were processed with Microsoft® Excel® 2013 and one-way ANOVA, with Duncan's post hoc test performed with SPSS.

Result and Discussion

Compositional analysis

Protein analysis: Kjeldahl method examined the protein content of chickpea, cowpea, and horse gram cooking water, finding that the protein content of the three cooking water was 1.5%, 2.04% and 0.5%, respectively, indicating that cowpea cooking water had the greatest protein content, followed by chickpea and horse gram cooking water (Table 2). It was discovered that the difference in protein content was highly significant (p<0.05). The protein content of pulse seeds was shown to be between 22.5-24.1%. In addition, when compared to the other two pulses, it is reasonable to believe that cowpea has a stronger leaching property (Sreerama *et al*., 2012) [50]. Aquafaba had an average protein content of 1.3% w/v, according to the protein analysis. Mustafa *et al*. (2020) [38] and Stantiall *et al*. (2018) [51] found a protein content of 1.5% and 0.95% of aquafaba, respectively.
Water diffusion into the seeds has been reported previously (Chigwedere *et al*., 2019) [9] to extract more water-soluble proteins such as albumin with a longer cooking time and a greater seed ratio that leached out into the water. Longer cooking increases the leaching of numerous water soluble components and pigments, as well as the deterioration of the latter, which is evident throughout the color spectrum (Alsalman *et al*., 2020) [3]. Meurer *et al*. (2020) [36] found that heating pulses for 20 minutes at a 1:3 ratio was the best, and this method was used in this investigation.

Moisture: Chickpea, cowpea, and horse gram cooking water (Fig. 3) had moisture content of 92.63%, 93.33% and 96.63%, respectively (Table 2). He *et al*. (2021) [19] found that the moisture content of aquafaba ranged from 92.4% to 94.2%, which supports the findings of this investigation.

Physiochemical analysis

pH: Table 2 shows that the pH of the chickpea cooking water is 6.1, whereas the pH of cowpea and horse gram is 6.7 and 6.5, respectively. The pH of centrifugated aquafaba, according to Buhl *et al*. (2019) [8], is 6.13, and the ANOVA tests reveal that it has a high importance, since it influences the functions of the pulse cooking water (Meurer *et al*., 2020) [36].

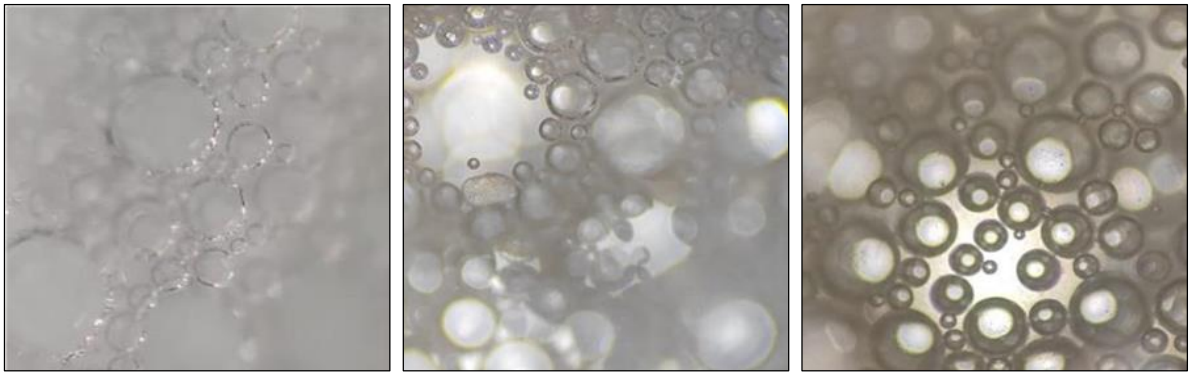
Fig 3: Pulse Cooking water a) Chickpea b) Cowpea c) Horse gram

Table 2: Results of Compositional and Physiochemical analysis

Pulse Cooking Water	Protein (%)	Moisture (%)	pH
Chickpea	1.50 ± 0.02^{b}	92.05 ± 0.72^{b}	6.13 ± 0.01^{c}
Cowpea	2.04 ± 0.06^{a}	93.9 ± 1.67^{b}	6.74 ± 0.02^{b}
Horse gram	0.50 ± 0.01^{c}	96.63 ± 1.01^{a}	6.50 ± 0.02^{a}

Data are expressed as means ± standard deviation (n = 3). Different letters (a–c) refer to significant differences among different drying methods according to Duncun test (p<0.05).

Microscopic examination of bubble: The bubbles created in the chickpea cooking water foam are tightly packed, and there are numerous and equally dispersed bubbles in a specific cross-section, as shown in Fig 4. Foam is more stable when bubbles are tightly packed (Depree and Savage, 2001) [12]. The bubbles in cowpea cooking water are abundant, however they are irregular elliptical bubbles with larger diameters that are not homogeneous in size, and the stability of the bubbles was seen to be inconsistent. The bubble size in the horse gram cooking water is almost uniform, but the interspace gaps are larger. According to Mustafa *et al*. (2020) [38], aquafaba takes greater mixing time to reduce particle size and achieve functional qualities equivalent to egg-based foam and emulsion, which might affect foam standardization.



a) b) c)

Fig 4: Microscopic Visualization of Foam: a) Chickpea cooking water b) Cowpea cooking water c) Horse gram cooking water

Functional analysis

Foaming Capacity and Stability: The foaming capacity of the samples was determined in percentages, with cowpea cooking water having the greatest with 132.12%, followed by chickpea with 117.02% and horse gram with 112.52% (p>0.05) in Table 3.

Because polysaccharides and their cross-linking with proteins have been documented to have a role in foam stability, aquafaba has a high carbohydrate content, which would contribute to strong foaming stability (Schramm, 2006) [44]. Similarly, cowpea and horse gram have a significant quantity of polysaccharides that aid in the production and stability of foam. Despite the fact that cowpea and chickpea flour have comparable carbohydrate ranges, horse gram has more (Sreerama *et al*., 2012) [50]. Because the amount of leaching is thought to be lower, the foaming capacity is also lower. Chickpeas, on the other hand, have a greater stability (32.33 mins), whereas cowpea and horse gram have a comparable range (24.33 min and 24.66 min). It's also possible to determine that seed and water ratios have an effect on foaming stability.

Gravity has an impact on foam stability since it causes liquid to drain from it (Hammershøj *et al*., 2004 [18]; Murray & Ettelaie, 2004) [37]. The liquid drainage per originally bound liquid following foam generation, as well as the liquid ratio in foam (L/L) over time, were used to assess foam stability (Buhl *et al*., 2019) [8]. The degree of foam dryness or wetness may be determined by the quantity of liquid retained in the foam.

With time, the liquid ratio in foam (L/L) declined dramatically (p<0.05), indicating that when liquid was drained from the foam, the remaining foam structure contained less moisture and became more dry in nature. Mustafa *et al*. (2020) [38] studied the foaming capacity and

stability of aquafaba and found that it has a foaming capacity of 400 to 500 percent. However, the aquafaba utilized in that study came from commercial chickpea cans, and the method for determining foaming capacity was different from the one employed here: whipping duration ranged from 1 minute in our study to 2-15 mins in Mustafa *et al*.'s work. (2020) [38]. This is obvious since a greater cooking water indicates a lower protein concentration in the cooking water, and both protein content and pH are critical for proper foaming. Flexible molecules that can minimize surface tension were also connected to superior foaming abilities by Kaur and Singh (2005) [24]. Although foams are thermodynamically unstable because their disintegration results in a drop in free energy, the kinetic mechanisms that cause them to break down can be gradual enough for them to be termed metastable for their intended use. Because liquid drains from the foam due to gravity, a measurement of foam stability as liquid retention is acceptable to classify the foam's dryness (Hunter *et al*., 2008) [22].

Pulse cooking water foam was described as being more wet because it had a greater liquid ratio, or more liquid compared to the foam volume. This differential in liquid retention may indicate a distinct intended purpose, since it may be more significant in high moisture-based culinary applications than egg white. Because all foam created changes with time, the influence of gravity was considered a significant element in both of the foam stability assessments.

Previous investigations of aquafaba as a viable egg white replacement choice in food foams have been supported by the opposing resilience to changes in chemical environment reported for the two protein sources (Mustafa *et al*., 2020 [38]; Stantiall *et al*., 2018) [51]. Gravity is the primary cause of liquid drainage from foam (Hammershj *et al*., 2004 [18]; Murray & Ettelaie, 2004) [37]. When comparing liquid drainage/initially bound liquid as a function of time, foam generated by centrifugated aquafaba and egg white were not substantially different.

Emulsion Capacity and Stability: Cowpea cooking water had the highest emulsion capacity (2.80mL), while all three samples had a similar emulsion capacity range, with chickpea having 2.33mL and horse gram having 2.06mL. Chickpea cooking water (1.73mL) emulsion stability is greater than cowpea cooking water (1.53mL) and horse gram cooking water (1.30mL) emulsion stability (Table 3). The hydrophobicity experiment demonstrated that longer boiling time denatured the pulse proteins, resulting in increased emulsion characteristics because the hydrophobic regions were exposed. High surface hydrophobicity improves emulsifying capabilities via enhancing film stiffness through hydrophobic interactions between protein molecules at the interface, according to Yanjun *et al*. (2014) [59]. According to Ma *et al*. (2011) [32], boiling chickpeas improves its emulsion activity, however Aguilera *et al*. (2009) [2] found that soaking and heating chickpea flour reduces its emulsion capacity, resulting in contradictory findings.

Alsalman *et al*. (2020) [3] found that proteins from centrifugated aquafaba had a faster and better capacity to adsorb at the oil-water interface and resist changes in the microstructure, as well as a higher stability. The EAI is positively correlated with surface hydrophobicity, since increased hydrophobicity tends to contribute to better protein integration and alignment at the oil-water interface, resulting in a higher EAI (Chung *et al*., 2017) [10].

Protein, as well as carbohydrates, were found to be important factors in the emulsifying ability of pulses in previous research (Shi *et al*., 2018) [47]. As a consequence, it's probable that a combination of protein and fiber contributed to chickpea's high EAI. The EAI did not correlate with the protein content determined in the previous study (Stantiall *et al*., 2018) [51], but it did correlate with the saponin content, which are well-known emulsifiers and surfactants due to their amphiphilic nature and ability to withstand boiling temperatures (Güçlü-Üstünda *et al*., 2007) [17]. Güçlü-Üstünda *et al*. (2007) [17] reported saponin concentrations in the pulse cooking water ranged from 8 to 14 mg/g, corresponding to 0.8–1.4 percent saponin content capable of surfactant activity (Güçlü-Üstünda *et al*., 2007) [17]. The fragility of their emulsions might be explained by the reduced saponin content in horse gram. Saponins were discovered to be packed closer together in a recent work by Chung and other researchers (Chung *et al*., 2017) [10], which screened unfavorable molecular interactions between the oil and water phases more efficiently. Saponins also produced smaller droplets during homogenization, lowering interfacial tension and resulting in increased EA and ES.

Because high temperatures denature proteins (LI-Chan *et al*., 1985) [30], boiling pulses are likely to have decreased their protein's emulsifying action. In concordance with a research on raw chickpea flour, significant EA was detected for all pulse cooking water, with values of around 50%. (Kaur *et al*., 2005) [24]. Pulse cooking water preferred the oil fraction to the water fraction, as evidenced by their higher OAC values than WAC (2–3 times higher) after centrifugation of the tubes (Alsaman *et al*., 2020) [3].

Total Phenolic Content (TPC): Table 3 shows that the TPC of chickpea, cowpea, and horse gram was 0.54, 0.40, and 0.71 mg GA eq/gm, respectively, compared to a prior research using a same cooking method: 60 minutes of boiling for lentils and 90 minutes for the other pulses (Xu and Chang, 2008) [58]. TPC levels in cowpea pulse cooking water were somewhat lower than in the others. There was no information on cowpea and horse gram cooking water in the literature.

This variation might be explained by the dry pulse's composition. Thermal deterioration is another possibility. Because of their hydrophilic properties, seeds may have produced phenolic chemicals during the early stages of the boil. Xu and Chang (2008) [58] observed that the boiling water of lentils contained high amount of phenolic compounds (1.25 mg/g) after as little as 30 min of boiling, while lower concentrations were determined after 45 and 60 min (0.84 mg/g). It's likely that the pulses in our investigation performed differently from the lentils in Xu and Chang's experiment, producing less phenolics in the pulse cooking water due to a shorter cooking period, which then degraded due to their heat sensitivity to heating (Xu and Chang, 2008) [58]. The oxidation of hydroxyls is one proposed route of heat degradation, as most phenolic compounds are nonconjugated, exposing these functional groups to degradation (Vallverd-Queralt *et al*., 2014) [55].

In terms of total phenolic content, the TPC of bean flour extracts differed considerably ($p<0.05$). TPC was greatest in horse gram extract (14.3 mg GAE/g), followed by cowpea (12.1 mg GAE/g) and chickpea (10.8 mg GAE/g). However, Siddhuraju and Backer (2007) [49] found TPC in cowpea cultivars ranging from 64 to 163 mg tannic acid equivalents/g.

Total Flavonoid Content (TFC): Flavonoids, which include flavones, flavanols, and condensed tannins, are common plant secondary metabolites. Antioxidant, anticancer, antiallergic, anti-inflammatory, and gastroprotective effects are all recognized for flavonoids. TFC values for chickpea, cowpea, and horse gram cooking water were 478.5, 562.0, and 270.5 mg QE/ml, respectively, in this investigation (Table 3). The chelating ability of flavonoids with aluminum was used to determine the TFCs of legume flours (III). TFC of all three pulse cooking waters was shown to be highly significant (p<0.05), similar to TPC. Horse gram extract, with 8.6 mg QE/g, had the greatest TFC, followed by cowpea (7.2 mg QE/g) and chickpea (4.8 mg QE/g). The observed TFC values are in agreement with those reported for chickpea and horse cotyledon fractions (Sreerama *et al*., 2010) [50]. There is currently minimal information on the quantity and characterization of pulse cooking water flavonoids. In milled fractions of chickpea and horse gram, flavonols such as quercetin, myricetin, and kaempferol were found (Sreerama *et al*., 2010) [50]. Aguilera *et al*. (2009) [2] recently reported the existence of pinocembrin, quercetin 3-O-rutinoside, kaempferol 3-Orutinoside, and 5,7-dimetoxyflavone in chickpea cultivars.

Antioxidantal activity: The phenolic extracts of cowpea, horse gram, and chickpea cooking water displayed significant DPPH (p<0.05) radical scavenging action, with the highest values for cowpea (30.23 percent), chickpea (11.51 percent), and horse gram (15.93 percent) (Table 3). The phenolic extract of horse gram flour demonstrated considerably stronger free radical scavenging activity (IC50 22.9 lg/ml) than the phenolic extracts of chickpea (IC50 31.4 lg/ml) and cowpea (IC50 48.2 lg/ml) flours (Sreerama *et al*., 2012) [50], contradicting the current findings. However, this might be owing to the level of leaching and heat deterioration.

It is worth mentioning that the capacity of cowpea, horse gram, and chickpea to scavenge free radicals was comparable to that of certain regularly ingested legumes (Madhujith & Shahidi, 2005) [33]. Cowpea extract' s observed free radical scavenging activity, on the other hand, was greater than that reported in the literature (Siddhuraju & Becker, 2007) [49]. This change in activity may be due to variables other than the extract, such as varietal differences, ambient conditions, and the extraction solvent utilized.

Table 4: Results of Functional analysis

Pulse Cooking Water	FC (%)	FS (min)	EC (ml)	ES (ml)	TPC (mg GA eq/gm)	TFC (mg QE/ml)	DPPH (%)
Chickpea	117.02 ± 0.41^a	32.33 ± 2.51^a	2.33 ± 0.15^b	1.73 ± 0.15^a	0.54±0.0001^a	478.50 ± 0.0015^b	11.51 ± 0.001^a
Cowpea	132.12 ± 1.40^a	24.33 ± 4.04^b	2.80 ± 0.10^b	1.53 ± 0.05^a	0.40±0.0003^a	562.00± 0.0005^a	30.23 ± 0.0005^c
Horse gram	112.52 ± 2.91^a	24.66 ± 0.57^b	2.06 ± 0.15^b	1.30 ± 0.10^b	0.71±0.0002^a	270.50 ± 0.001^c	15.93 ± 0.0011^b

Data are expressed as means ± standard deviation (n = 3). Different letters (a–c) refer to significant differences among different drying methods according to Duncan test (p<0.05).

The effects of pH on some of the functional properties were also investigated. It was found that the foaming capacity and stability, emulsifying capacity and emulsion stability were greatly affected by pH levels (Fig 5).

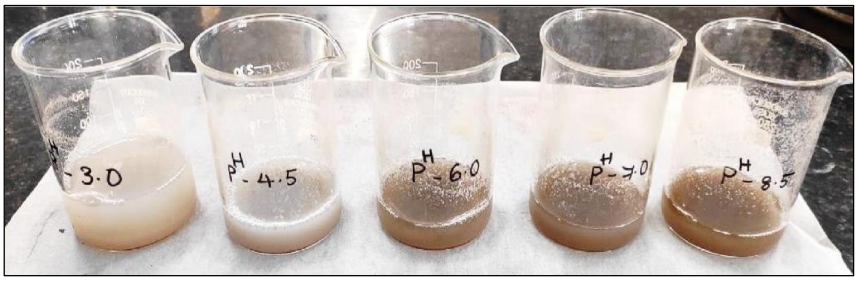


Fig 5: pH optimization of Cowpea cooking water with pH 3, pH 4.5, pH 6, pH 7, pH 8.5

Foaming Capacity and Stability: It was discovered that variations in pH level within the examined range had a minor impact on the foam capacity of the samples with varied pH. Earlier research on the foam capacity of egg white revealed a pH influence (Hammershøj *et al*., 2004) [18]. The sampe of pH 6 (137%) and pH 3 (136.66%) had the highest foam capacity, whereas pH 8.5 had the lowest (Table 5).

The liquid ratio was considerably impacted (p<0.05) by changes in the pH of cowpea cooking water (Fig 6). At varied pH levels, displayed substantially distinct liquid ratio patterns (p<0.05). Proteins are responsible for good foaming qualities, according to Stantiall *et al*. (2018) [51], which is a logical rationale for the linear rise because longer cooking times can solubilize more water-soluble proteins. Previous research has revealed that FC is stronger at low pH levels due to increased net charges on proteins, which reduce hydrophobic interactions while increasing protein flexibility (Ragab *et al*., 2004) [40]. Stantiall *et al*. (2018) [51] achieved lower results than those obtained here. However, the pH of the cooking water was not altered in that study, and reducing the pH of the solution is critical for greater foaming capacities (Lafarga *et al*., 2019) [28]. The effect of pH on protein FC is connected to a change in their net charge, which influences foam formation and film viscoelastic characteristics (Drago and González, 2000) [13].

The pH of cowpea liquid had a substantial impact on both liquid ratio in foam and liquid drainage, with aquafaba foam at pH 6 being very stable for 33 minutes and the sample with pH 8.5 exhibiting the least stability. The findings suggest that protein surface charge affects foam stability and prior research has shown that pH samples around the isoelectric area, where the net charge of the proteins is zero and electrostatic forces are small, have higher foam stability (Hammershj *et al*., 2004) [18]. Because of the shorter distance between proteins at this pH, hydrophobic interactions and hydrogen bonding between proteins may be strengthened, resulting in significant interfacial film development and hence foam stabilization (Hammershj *et al*., 2004) [18]. To ensure

adequate foaming qualities, proteins must be able to create a film that stabilizes the air/water interface (Zhang, Dalgleish, & Goff, 2004) [61] and reduce the surface tension (Hammershj *et al*., 2004) [18].

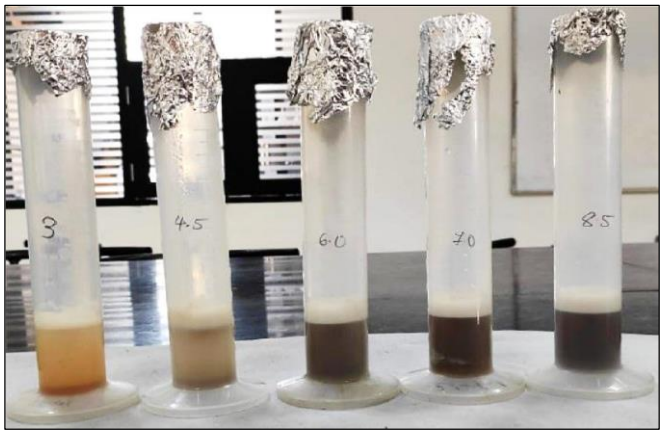


Fig 6: Foam Capacity and Foam Stability of cowpea cooking water in varying pH.

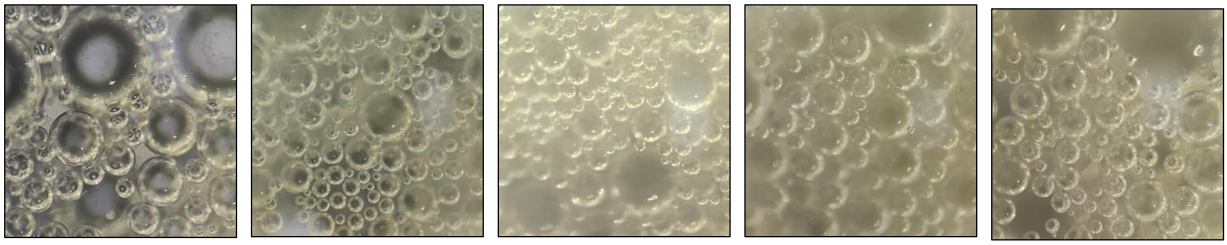
Emulsion Capacity and Stability: The results for EC and ES were similar to those for FC and FS, with lower pH and cooking water values resulting in higher EC and ES. Maximum EC and ES was shown by sample prepared with pH 6. The findings are similarly consistent with those seen in other legume-derived proteins, where both FC and EC were greater at lower pH levels (Lafarga *et al*., 2019) [28]. This is because the hydrophilic-lipophilic balance, which is pH dependent, affects both the EC and the ES of proteins (Ragab *et al*., 2004) [40]. The protein content of the aquafaba obtained by boiling the chickpeas at a lower cooking water had a higher protein concentration in the current study, suggesting that the protein content of the aquafaba obtained by boiling the chickpeas at a lower cooking water had a higher protein concentration. Proteins are surfactants that have a hydrophilic "head" group that interacts with water and a lipophilic "tail" group that interacts with oil and helps to produce and stabilize emulsions (McClements, 2007) [35]. When compared to alkaline conditions, Gharsallaoui *et al*. (2009) [16] reported higher EC and ES of pea proteins at pH 2.4, which they attributed to lower protein adsorption combined with interfacial film reorganisation, which prevented film rupture and increased ES, confirming the findings of the current study. Again, just a few research looked at pulse cooking water's techno-functional capabilities. The ANOVA revealed that the hypothesized factor interaction model for ES was correct, and that pH impacted FS (p<0.05).

Changes in the pH level of centrifugated aquafaba, on the other hand, altered the emulsifying capacity and emulsifying stability index. These findings contradict those of Zhang *et al*. (2004) [61], who found a much-reduced emulsifying activity index of samples at the isoelectric point of pH 5.0 of chickpea proteins isolates, whereas we found low values at pH 3.0 and pH 4.5 and the maximum EAI and ESI for aquafaba at pH 6. The reduced EC and ES for centrifugated aquafaba at pH 4.5 might be explained by the zero net charge at pH 4.6, which results in weak attractive forces between adsorbed proteins on the interfacial coated protein region (Zhang *et al*., 2009) [61]. The protein solubility of chickpea isolate has previously been found to be very poor at pH 4-7 (Tontul *et al*., 2018) [54], however this was not the case for the current samples. Other variables impacting the emulsifying activity and stability of the proteins, such as internal factors of conformation stability and surface hydrophobicity, might be to blame for the current observation of both a low EAI and a low ESI at pH 3. (Hu *et al*., 2015) [21].

The change in pH of centrifugated aquafaba affected the mean particle diameter in the same way that it influenced the emulsifying activity and stability index. With higher pH value, lower volume weighted diameter was observed. It is commonly known that emulsions with tiny particle diameters have greater stability than emulsions with larger particle diameters (McClements *et al*., 2007) [35]. For emulsions based on cowpea cooking water, no substantial instability related to big particles was detected, however McClements *et al*. (2007) [35] reported a significant influence on the isoelectric point of emulsions based on lentil or pea protein. Microscopically, there was a tendancy toward poor stability and bigger droplets at pH 3.0-4.5 and vice versa at pH 6, with higher stability indexes and smaller droplets (Table 5). According to the Stokes equation on settling velocity, other characteristics such as emulsion droplet size homogeneity, emulsion viscosity, and density differential between water and oil phase will also impact emulsion stability (Yi *et al*., 2014) [60].

Microscopic examination of bubbles: Because multiple bubbles may be visible in a cross section of a sample with pH 3, microscopic observation of the sample with pH 3 suggests that it has foaming ability (Fig 7). The uniformity of bubbles and the quantity of spaces between the bubbles, both of which are positive for the sample, suggest foam stability. The pH 4 sample has a lot of spaces between the bubbles, and the data shows that it has the least foaming capacity and stability. The pH 6 sample was discovered to have the highest capacity and stability, as evidenced by numerous bubbles with less voids in between and numerous elliptical bubbles. The pH 7 sample similarly lacked considerable capacity and stability, with bigger voids, larger bubble sizes, and fewer vacancies. The sample with pH 8.5 has the lowest capacity and stability values, as seen by the small number of bubbles in a cross section, non-uniform size, and substantially bigger voids.

When a mixer's rotating speed is increased, the mean bubble diameter shrinks. The viscosity of the liquid phase influences the size of the bubbles; a lower viscosity leads in bigger mean bubbles. Small bubbles will shrink and huge bubbles will develop as a result of the disproportion. It's possible that the growth in huge bubbles is attributable to the fact that large bubbles develop at the expense of small bubbles, and the bubble size distribution shifts with time (Mustafa *et al*., 2020) [38].



a) b) c) d) e)

Fig 7: Microscopic view of Cowpea cooking water foam pH Optimization a) pH 3 b) pH 4.5 c) 6 d) pH 7 e) pH 8.5

Table 5: Foaming Capacity & Stability and Emulsion Capacity & Stability of pH Optimized Cowpea cooking water

pH	FC (%)	FS (min)	EC (mL)	ES (mL)
3	136.66 ± 1.52^{a}	29.66 ± 1.52b	1.76 ± 0.05c	0.96 ± 0.11c
4.5	126.00 ± 3.00^{c}	25.00 ± 1.00^{c}	2.23 ± 0.11^{b}	1.23 ± 0.15^{b}
6	137.00 ± 2.64^{a}	33.66 ± 1.52^{a}	3.03 ± 0.15^{a}	1.60 ± 0.10^{a}
7	117.00 ± 2.64^{c}	23.33 ± 1.52^{c}	2.73 ± 0.15^{a}	1.33 ± 0.05^{b}
8.5	095.66 ± 2.08^{d}	18.33 ± 1.52^{d}	2.30 ± 0.10^{b}	1.23 ± 0.11^{b}

Data are expressed as means ± standard deviation (n = 3). Different letters (a–d) refer to significant differences among different drying methods according to Duncan test (p<0.05).

It was observed that the optimum pH condition for the development of pulse cooking water powder with higher foaming activity and emulsifying activity is at pH 6 (Fig. 8). The overall characteristics of obtained product after time regulated is deduced into the (Table 6).

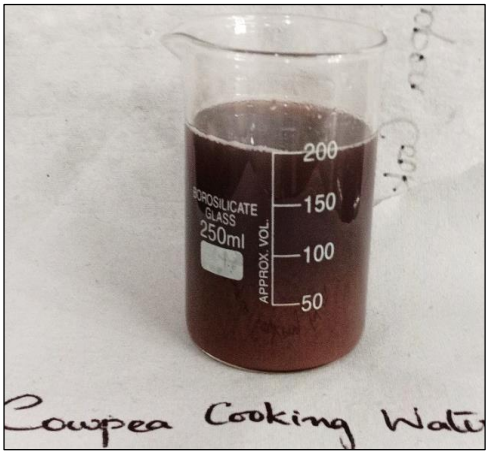


Fig 8: Cowpea cooking water optimized to pH 6

The sample solution did not change significantly in colour following vacuum oven drying, although it did darken slightly after tray drying (Fig 9). The black coloration of the cooking water is caused by the presence of certain melanin-like pigments concentrated in the seed's eye. It varies a lot depending on the cultivar (Saunders, 1959) [43]. The deeper coloration might be owing to Maillard and caramelisation processes triggered by the drying method's high temperature (500°C) (He *et al*., 2021) [19].

Due to the presence of polysaccharides such as fibres and seed debris after pressure cooking, the texture of the sample liquid was slightly sticky. The sample became significantly more viscous after vacuum oven drying, and putting it in a tray drier resulted in a thick, rubbery consistency. He *et al*. (2021) [19] found that rotovap drying yielded the highest aquafaba yield by weight (8.78 ± 0.09%), but the final product exhibited gel-like qualities, which they ascribed to Maillard and caramelisation processes produced by the high temperature (50 °C) utilized in this drying technique. The formation of covalent conjugates between proteins and polysaccharides during oven drying for more than 12 hours at 80 ^{0}C due to oxidation and thermal-induced reactions (Maillard and caramelisation) of aquafaba components (e.g. polysaccharide and protein) may have contributed to higher emulsion stability, but there was evidence of unsatisfactory browning in oven-dried samples (He *et al*., 2021) [19]. 1-octen-3-one, hexanal, 3-isopropyl-2-methoxypyrazine, 3-sec-butyl-2-methoxypyrazine, 3-isobutyl-2-methoxypyrazine, and other substances contribute to the unpleasant aroma of pulses, which is commonly referred to as "beany" or "nutty" (Roland *et al*., 2017) [42]. However, the sample's colour and odour were not significantly affected by vacuum oven drying. Because the drying process used in this study does not produce satisfactory results, it is not recommended for commercial use. Later the obtained dried sample was made into powder using pestle and mortar (Fig. 10).

Table 6: Sensorial Results after Drying of Cowpea cooking water

Drying method	Colour	Texture	Odour
Vacuum Oven (after 4hrs)	Violet- brown	Viscous	Nutty odour
⇩	⇩	⇩	⇩
Tray Drier (after 4hrs)	Brown	Thick- rubbery	Very less nutty odour

Fig 9: Sample after Vacuum oven drying and Tray drying

Fig 10: Cowpea Cooking Water Powder

Yield: The total time taken for the entire process is 1500 min, where 960 min was taken for soaking, 60 min for pressure cooking and 240 min by each drying processes employed. The approximate yield of PCW was 0.8g/g pulse while the yield of powder was 0.04g/g pulse. The process employed by Stantiall *et al*., (2018) [51] required about 120 min of processing except drying and yielded approximately 0.6g PCW/g pulse.
According to Alsalman *et al*. (2020) [3], the yield increased as the water proportion increased and the seed proportion decreased. Additionally, it was claimed that using a seed-to-water ratio of 1:4 for 15 minutes produced the maximum yield. Approximately 10-15% of the solids (dry seed weight) are lost during soaking (22 °C; 16 hours) and heating (boiling water; 65 minutes) under atmospheric pressure or under high pressure (retort; 120 °C; 15 minutes). Proteins and carbohydrates make up the majority of the lost solids (Shi *et al*., 2018) [47]. Utilizing less water and energy is essential for producing PCW at larger scales using environmentally friendly procedures. Increasing the use of hydrolytic enzymes and other techniques, including ultrasonic or microwave assisted extraction, may also increase the yield and usefulness of aquafaba.

Fat absorption capacity: The powder's FAC was 2.03g/g. According to research by Worrasinchai *et al*. (2006) [56], water-soluble polysaccharides were able to absorb some oil, but other macromolecules are also likely to be attributed. It has been demonstrated that legume proteins can bind oil through their hydrophobic regions (Laca *et al*., 2010) [27]. Oil absorption by fiber, both soluble and insoluble, has also been reported (McClements *et al*., 2007) [35]. OAC levels (1.1 g/g) were found in a study on raw chickpea flour using a similar methodology (Alsalman *et al*., 2020) [3]. Boiling may have denatured the pulse proteins, exposing their hydrophobic surfaces to the media and boosting the PCW's oil affinity (He *et al*., 2021) [19]. Damian *et al*. (2018) [11] measured the FAC of freeze-dried aquafaba as 3.2g/g. The characteristics of aquafab may change as a result of molecular regions getting exposed during cooking and as a result of changes in aquafaba composition. In addition, it has been demonstrated that pressure cooking causes protein dissociation, revealing more binding sites and enhancing the characteristics (Xu *et al*., 2008) [58]. They also noticed that aquafaba OAC increased with longer cooking times and greater chickpea/water ratios. Despite the shorter cooking time in our trial, the greater chickpea/water ratio (1:1 vs. 1:1.75) may have had a more significant impact on the rise in FAC.

Foaming capacity & stability: The foam capacity and stability (Fig 11) value of sample have dropped when dried to powder, as seen by the powder's 20.37± 0.97% foam capacity and 21.46± 0.90 minute foam stability. According to Liao and Mangino's (1987) [29] research, foam generation is dependent on the proteins' solubility, which is correlated with their hydrophobicity. The resulting powder has a moderate amount of water solubility.

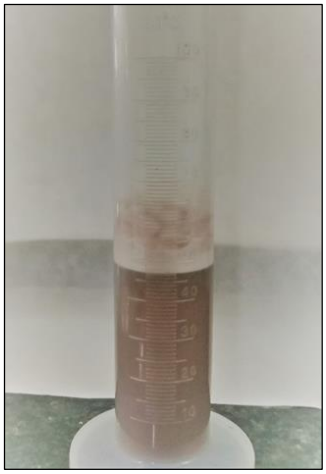


Fig 11: Foam Capacity and Foam Stability of cowpea cooking water powder.

Emulsion Capacity & Stability: The PCW had 3.03 mL of emulsifying capacity and 0.97 mL of emulsion stability compared to the powder's 1.91 mL and 0.97 mL, respectively (Fig 12). The amounts would be 20 times more concentrated if cooking water were a dry powder, potentially up to 1.1 TUI/mg for chickpeas and 3.5 TUI/mg for beans. According to Avilés-Gaxiola *et al*. (2018) [4] and Shi *et al*. (2018) [47], raw legumes typically contain 8.1–16 TUI/mg of trypsin inhibitors for chickpeas and 16 TUI/mg of trypsin inhibitors for beans. Since trypsin inhibitors are easily inactivated by physical processes (heat, extrusion, ultrasound, and ultrafiltration), chemical processes (acids, bases), and biological processes (germination and fermentation), dry powder from legume cooking water may include small levels of trypsin inhibitors (Avilés-Gaxiola *et al*. 2018) [4]. Therefore, the impacts of the drying procedure used may be to blame for the decrease in emulsifying activity. Boiling legumes likely reduced the protein's ability to emulsify since high temperatures denature proteins (LI-Chan *et al*., 1985) [30].

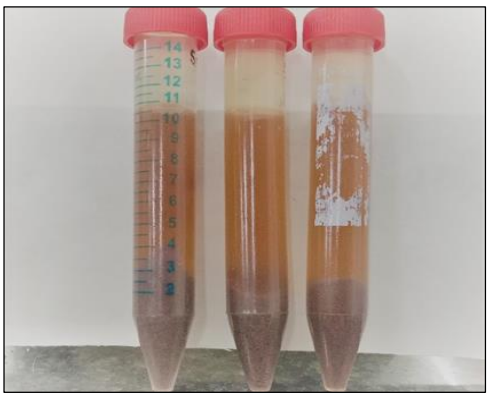


Fig 12: Emulsion activity of cowpea cooking water powder

Swelling capacity: The swelling capacity shows how much a powder or flour would expand in proportion to its original volume when soaked in water. The powder that was obtained had a 16.1 mL/g swelling capacity. By absorbing water, the amorphous portion of the starch found in the powder can significantly enlarge. The swelling capacity ranged from 14.0-36.5g/mL in a study on instant cowpea soup powder, which is equivalent to the outcomes of the current investigation (Falade *et al*., 2021) [14]. According to research papers, the particle size, variety, and type of processing procedures affect the swelling capacity of flours, which may indicate that there is non-covalent interaction between the molecules of starch (Suresh, 2013) [52]. The ratio of amylose to amylopectin, the chain length and molecular weight distribution, the degree of branching and conformation, and the bonding forces inside the starch granules were some of the variables that influenced the swelling (Adebowale, 2002) [1]. The formation of a large number of crystallites could also affect stability and limit granular swelling (Hoover & Ratnayake, 2002) [20].

Water absorption capacity: The powder's WAC was 2.34 g/g range. Haricot bean and whole green lentil freeze-dried powders only absorbed 0.1 g of water per g of powder in the Boye *et al*. (2010) [7] study. On the other hand, moderate WAC was found for split yellow peas (2.20 ± 0.04) and garbanzo beans (1.46 ± 0.05 g/g). More water soluble carbohydrates were present in chickpea and pea PCW than in beans and lentils. Both soluble and insoluble fiber are abundant in cowpeas, and both types of fiber have a high ability to absorb water (Falade *et al*., 2021) [14]. Given that it has been shown that water-soluble polysaccharides have a high affinity for water, it is plausible that these carbohydrates, most likely oligosaccharides, contributed to water binding (Liu *et al*., 2007) [31]. Spray-dried aquafaba (1.92 0.09 g/g) had a lower WAC than freeze-dried aquafaba (4.36 0.20 g/g), which was manufactured under ambient conditions. According to Damian *et al*. (2018) [11], freeze-dried aquafaba had a WHC of 1.5g/g. The conditions for soaking and cooking, as well as variations in the composition and concentration, are the primary determinants of value. The enhanced WHC observed with this shorter cooking time is supported by Alsalman *et al*. (2020) [3], who found that increasing cooking time from 15 to 60 min significantly lowered aquafaba WHC (from 2.4 g/g to 1.6 g/g).

Microscopic examination of bubbles: Larger bubbles were seen in the foam (Fig 13), indicating less homogeneity and bubble distribution. Foams with smaller bubbles and higher homogeneity demonstrate this. In their study of faba bean protein foam bubbles, Martnez-Velasco *et al*. (2018) [34] discovered that high- intensity ultrasound reduced the average bubble diameter from 364µ m to 190µm. These findings comply with those of Xiong *et al*. (2018) [57], who discovered that, following sonication, pea protein isolate foam displayed smaller initial bubble sizes and more uniform bubbles, especially for the highest intensity used (Nguyen *et al*., 2020) [39].

According to Bennion *et al*. (1997) [5], fine, uniform-sized bubbles give the mixture stability and a suitable texture for food. Large bubbles and size variations will cause the mixture to become unstable, giving the finished product an uneven texture (Meurer *et al*., 2020) [36].

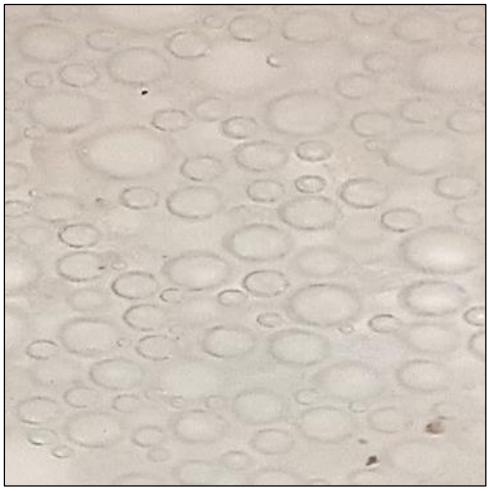


Fig 13: Microscopic view of Cowpea cooking water foam

Conclusion

In liquid form, pulse cooking water was shown to offer significant potential as a beneficial component in meals. They are useful for a variety of food applications due to their high foaming and emulsifiability. Chickpea cooking water, for example, showed higher foaming activities, but cowpea cooking water possessed acceptable emulsion capacity. Many research has focused on the properties of chickpea cooking water, but this study tested the capabilities of a different method: cowpea and horse gram cooking water analysis. Horse gram's results did not meet expectations. As a result, cowpea cooking water was the study's main emphasis. The shortcomings of its performance as a functional component were evaluated, and the pH was adjusted from pH 3, pH 4.5, pH 6, pH 7, pH 8.5 to optimize it. The sample at pH 6 produced good findings, and this sample was dried for convenience.

Finally, pulse cooking water may be upcycled into a variety of culinary components, including foaming agents, emulsifying agents, thickeners, and texturizers. Further research into the functional qualities of cowpea cooking water, as well as the optimization of other factors, might lead to the creation of a new vegan functional ingredient analogous to Aquafaba. Other legumes or pulses can be investigated for production and optimization. For sustainable food production, more work on their applications is encouraged.

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Reference

1. Adebowale KO, Afolabi TA, Lawal OS. Isolation, chemical modification and physicochemical characterisation of Bambarra groundnut (*Voandzeia subterranean*) starch and flour. Food chemistry. 2002 Aug;78(3):305-11.
2. 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 Nov;57(22):10682-8.
3. Alsalman FB, Tulbek M, Nickerson M, Ramaswamy HS. Evaluation and optimization of functional and antinutritional properties of aquafaba. Legume Science. 2020 Jun;2(2):e30.
4. Avilés-Gaxiola S, Chuck-Hernández C, Serna Saldívar SO. Inactivation methods of trypsin inhibitor in legumes: a review. Journal of Food Science. 2018 Jan;83(1):17-29.
5. Bennion EB, Bamford GS, Bent AJ. Cake-making processes. In the technology of cake making. Springer, Boston, MA, 1997, 251-274.
6. Bhartiya A, Aditya JP, Kant L. Nutritional and remedial potential of an underutilized food legume horse gram (*Macrotyloma uniflorum*): A review. JAPS: Journal of Animal & Plant Sciences, 2015 Aug, 25(4).
7. Boye J, Zare F, Pletch A. Pulse proteins: Processing, characterization, functional properties and applications in food and feed. Food research international. 2010 Mar;43(2):414-31.
8. Buhl TF, Christensen CH, Hammershøj M. Aquafaba as an egg white substitute in food foams and emulsions: Protein composition and functional behavior. Food Hydrocolloids. 2019 Nov;96:354-64.
9. Chigwedere CM, Flores JN, Panozzo A, Van Loey AM, Hendrickx ME. Instability of common beans during storage causes hardening: The role of glass transition phenomena. Food Research International. 2019 Jul;121:506-13.
10. Chung C, Sher A, Rousset P, Decker EA, McClements DJ. Formulation of food emulsions using natural emulsifiers: Utilization of quillaja saponin and soy lecithin to fabricate liquid coffee whiteners. Journal of Food Engineering. 2017 Sep;209:1-1.
11. Damian JJ, Huo S, Serventi L. Phytochemical content and emulsifying ability of pulses cooking water. European Food Research and Technology. 2018 Sep;244(9):1647-55.
12. Depree JA, Savage GP. Physical and flavour stability of mayonnaise. Trends in Food Science & Technology. 2001 May;12(5-6):157-63.
13. Drago SR, Gonzalez RJ. Foaming properties of enzymatically hydrolysed wheat gluten. Innovative Food Science & Emerging Technologies. 2000 Dec;1(4):269-73.
14. Falade KO, Adeniyi OG. Instant soups from cowpea varieties using foam-mat drying. LWT. 2021 Nov;151:112-191.
15. Food and Agriculture Organization of the United Nations, FAOSTA Database, FAO, 2016 Dec. www.fao.org/faostat.
16. Gharsallaoui A, Cases E, Chambin O, Saurel R. Interfacial and emulsifying characteristics of acid-treated pea protein. Food Biophysics. 2009 Dec;4(4):273-80.
17. Güçlü-Üstündağ Ö, Mazza G. Saponins: properties, applications and processing. Critical reviews in food science and nutrition. 2007 Mar;47(3):231-58.
18. Hammershøj M, Peters LV, Andersen HJ. The significance of critical processing steps in the production of dried egg albumen powder on gel textural and foaming properties. Journal of the Science of Food and Agriculture. 2004 Jul;84(9):1039-48.
19. He Y, Meda V, Reaney MJ, Mustafa R. Aquafaba, a new plant-based rheological additive for food applications. Trends in Food Science & Technology. 2021 May;111:27-42.
20. Hoover R, Ratnayake WS. Starch characteristics of black bean, chick pea, lentil, navy bean and pinto bean cultivars grown in Canada. Food chemistry. 2002 Sep;78(4):489-98.
21. Hu H, Cheung IW, Pan S, Li-Chan EC. Effect of high intensity ultrasound on physicochemical and functional properties of aggregated soybean β-conglycinin and glycinin. Food Hydrocolloids. 2015 Mar;45:102-10.
22. Hunter TN, Pugh RJ, Franks GV, Jameson GJ. The role of particles in stabilising foams and emulsions. Advances in colloid and interface science. 2008 Mar;137(2):57-81.
23. Ishara JR, Sila DN, Kenji GM, Buzera AK, Mushagalusa GN. Nutritional and Physical Attributes of Maize-mushroom Complementary Porridges as Influenced by Mushroom Species and Ratio. Am J Food Nut. 2018;6(1):17-27.
24. Kaur M, Singh N. Studies on functional, thermal and pasting properties of flours from different chickpea (*Cicer arietinum* L.) cultivars. Food chemistry. 2005 Jul;91(3):403-11.
25. Khalid II, Elhardallou SB. The effect of pH on foaming properties of cowpea (*Vigna ungiculata* L. walp) flour and protein isolates. Journal of Nutrition and Food Sciences. 2015 Jan;5(4):100-0385.
26. Kim DO, Jeong SW, Lee CY. Antioxidant capacity of phenolic phytochemicals from various cultivars of plums. Food chemistry. 2003 Jun;81(3):321-6.
27. Laca A, Sáenz MC, Paredes B, Díaz M. Rheological properties, stability and sensory evaluation of low-cholesterol mayonnaises prepared using egg yolk granules as emulsifying agent. Journal of Food Engineering. 2010 Mar;97(2):243-52.
28. 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. International Journal of Gastronomy and Food Science. 2019 Dec;18:100-177.
29. Liao SY, Mangino ME. Characterization of the composition, physicochemical and functional properties of acid whey protein concentrates. Journal of Food Science. 1987 Jul;52(4):1033-7.
30. LI-Chan EU, Nakai S, Wood DF. Relationship between functional (fat binding, emulsifying) and physicochemical properties of muscle proteins. Effects of heating, freezing, pH and species. Journal of Food Science. 1985 Jul;50(4):1034-40.
31. Liu W, Peffley EB, Powell RJ, Auld DL, Hou A. Association of seedcoat color with seed water uptake, germination, and seed components in guar (*Cyamopsis tetragonoloba* (L.) Taub). Journal of arid Environments. 2007 Jul;70(1):29-38.
32. Ma Z, Boye JI, Simpson BK, Prasher SO, Monpetit D,

Malcolmson L. Thermal processing effects on the functional properties and microstructure of lentil, chickpea and pea flours. Food Research International. 2011 Oct;44(8):2534-44.
33. Madhujith, Terrence, Fereidoon Shahidi. Beans: A source of natural antioxidants, 2005.
34. Martínez-Velasco A, Lobato-Calleros C, Hernández-Rodríguez BE, Román-Guerrero A, Alvarez-Ramirez J, Vernon-Carter EJ. High intensity ultrasound treatment of faba bean (*Vicia faba* L.) protein: Effect on surface properties, foaming ability and structural changes. Ultrasonics sonochemistry. 2018 Jun;44:97-105.
35. Mcclements DJ. Critical review of techniques and methodologies for characterization of emulsion stability. Critical reviews in food science and nutrition. 2007 Sep;47(7):611-49.
36. Meurer MC, De Souza D, Marczak LD. Effects of ultrasound on technological properties of chickpea cooking water (aquafaba). Journal of Food Engineering. 2020 Jan;265:109-688.
37. Murray BS, Ettelaie R. Foam stability: proteins and nanoparticles. Current opinion in colloid & interface science. 2004 Dec;9(5):314-20.
38. Mustafa R, Reaney MJ. Aquafaba, from food waste to a value-added product. Food Wastes and By-products: Nutraceutical and Health Potential, 2020 Jan, 93-126.
39. Nguyen TM, Nguyen TP, Tran GB, Le PT. Effect of processing methods on foam properties and application of lima bean (*Phaseolus lunatus* L.) aquafaba in eggless cupcakes. Journal of Food Processing and Preservation. 2020 Nov;44(11):e14-886.
40. Ragab DM, Babiker EE, Eltinay AH. Fractionation, solubility and functional properties of cowpea (*Vigna unguiculata*) proteins as affected by pH and/or salt concentration. Food chemistry. 2004 Feb;84(2):207-12.
41. Ratanapariyanuch K, Tyler RT, Shim YY, Reaney MJ. Biorefinery process for protein extraction from oriental mustard (*Brassica juncea* (L.) Czern.) using ethanol stillage. AMB express. 2012 Dec;2(1):1-9.
42. Roland WS, Pouvreau L, Curran J, Van de Velde F, De Kok PM. Flavor aspects of pulse ingredients. Cereal Chemistry. 2017 Jan;94(1):58-65.
43. Saunders AR. Inheritance in the cowpea (*Vigna sinensis* Endb.) I. Colour of the seed coat. South African Journal of Agricultural Science. 1959 Sep;2(3):285-307.
44. Schramm G. Reologia e reometria: Fundamentos teóricos e práticos. Artliber Ed., 2006.
45. Serventi L. Soaking water composition. In Upcycling Legume Water: From wastewater to food ingredients. Springer, Cham., 2020, 27-39.
46. Sharma S, Singh N, Singh B. Effect of extrusion on morphology, structural, functional properties and *in vitro* digestibility of corn, field pea and kidney bean starches. Starch-Stärke. 2015 Sep;67(9-10):721-8.
47. Shi L, Arntfield SD, Nickerson M. Changes in levels of phytic acid, lectins and oxalates during soaking and cooking of Canadian pulses. Food Research International. 2018 May;107:660-8.
48. Shim YY, Mustafa R, Shen J, Ratanapariyanuch K, Reaney MJ. Composition and properties of aquafaba: Water recovered from commercially canned chickpeas. JoVE (Journal of Visualized Experiments). 2018 Feb;10(132):e56-305.
49. Siddhuraju P, Becker K. The antioxidant and free radical scavenging activities of processed cowpea (*Vigna unguiculata* (L.) Walp.) seed extracts. Food chemistry. 2007 Jan;101(1):10-9.
50. Sreerama YN, Sashikala VB, Pratape VM. Phenolic compounds in cowpea and horse gram flours in comparison to chickpea flour: Evaluation of their antioxidant and enzyme inhibitory properties associated with hyperglycemia and hypertension. Food Chemistry. 2012 Jul;133(1):156-62.
51. Stantiall SE, Dale KJ, Calizo FS, Serventi L. Application of pulses cooking water as functional ingredients: The foaming and gelling abilities. European Food Research and Technology. 2018 Jan;244(1):97-104.
52. Suresh C. Assessment of functional properties of different flours. African journal of agricultural research. 2013 Oct;8(38):4849-52.
53. Thakur P, Dilta BS, Gupta YC, Mehta DK, Kumar P. Effect of planting dates, mulching and application of ga3 on seed yield and quality of marigold (*Tagetes erecta* L.) cv. 'Pusa Narangi Gainda'. Int. J Curr. Microbiol. App. Sci. 2019;8(4):3028-39.
54. Tontul İ, Kasimoglu Z, Asik S, Atbakan T, Topuz A. Functional properties of chickpea protein isolates dried by refractance window drying. International Journal of Biological Macromolecules. 2018 Apr;109:1253-9.
55. Vallverdú-Queralt A, Regueiro J, Martínez-Huélamo M, Alvarenga JF, Leal LN, Lamuela-Raventos RM. A comprehensive study on the phenolic profile of widely used culinary herbs and spices: Rosemary, thyme, oregano, cinnamon, cumin and bay. Food chemistry. 2014 Jul;154:299-307.
56. Worrasinchai S, Suphantharika M, Pinjai S, Jamnong P. β-Glucan prepared from spent brewer's yeast as a fat replacer in mayonnaise. Food hydrocolloids. 2006 Jan;20(1):68-78.
57. Xiong T, Xiong W, Ge M, Xia J, Li B, Chen Y. Effect of high intensity ultrasound on structure and foaming properties of pea protein isolate. Food Research International. 2018 Jul;109:260-7.
58. Xu B, Chang SK. Effect of soaking, boiling, and steaming on total phenolic content and antioxidant activities of cool season food legumes. Food chemistry. 2008 Sep;110(1):1-3.
59. Yanjun S, Jianhang C, Shuwen Z, Hongjuan L, Jing L, Lu L, *et al*. Effect of power ultrasound pre-treatment on the physical and functional properties of reconstituted milk protein concentrate. Journal of Food Engineering. 2014 Mar;124:11-8.
60. Yi J, Li Y, Zhong F, Yokoyama W. The physicochemical stability and *in vitro* bioaccessibility of beta-carotene in oil-in-water sodium caseinate emulsions. Food Hydrocolloids. 2014 Mar;35:19-27.
61. Zhang Z, Dalgleish DG, Goff HD. Effect of pH and ionic strength on competitive protein adsorption to air/water interfaces in aqueous foams made with mixed milk proteins. Colloids and Surfaces B: Biointerfaces. 2004 Mar;34(2):113-21.