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Production of Vegetables Soup Powder Supplemented with Two Plant Protein Sources

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ABSTRACT

Dried quick soups are gaining popularity due to their convenience. This study aimed to develop and evaluate nutritious vegetable-based soup powders enhanced with quinoa and chia seeds flours in varying ratios (30%, 50%, or a combination with 25% of each). Incorporating quinoa and chia seeds flours increased the protein, fat, phosphorus, and magnesium content of the soup mixes but decreased potassium levels. Additionally, the presence of these flours improved phenolic content, antioxidant activity, and lightness (L-value) and yellowness (b-value), while reducing redness. The physical properties of the soup mixes, such as bulk density and water activity, were minimally affected, while solubility was improved. Rheological and sensory evaluations revealed that adding 30% quinoa seeds flour to the vegetable soup mix enhanced flow behavior (consistency value of 20.39 dynes. Sn/cm^2) and sensory attributes (color, odor, texture, and taste) compared to the control or other tested soup mixes.

1. Introduction

Consuming nutrient-deficient foods can eventually lead to malnutrition and associated diseases. Diets based primarily on cereals can also contribute to this condition. This issue can be addressed by providing easily prepared, nutrient-enriched foods. Dried soup powder plays a significant role in meeting the needs of both current and future consumers (Krejcova, et.al 2007). Dried soup powders offer several advantages, including stability against enzymatic and oxidative spoilage, and maintaining flavor at room temperature for extended periods (6–12 months). Additionally, they can be quickly reconstituted, making them ideal for busy families, hotels, restaurants, hospitals, and other institutions (Rekha et.al 2008). Vegetables are an essential component of the human diet, providing crucial micronutrients such as water -soluble vitamins (Vitamin C and B vitamins like B6 and folate) and fat-soluble vitamins (particularly A and E). They also supply essential minerals (especially potassium, sodium, iron, etc.) that are fundamental for proper development and various bodily functions, including digestion (Aderinola and Abaire, 2019). Vegetables can originate from various plant parts, including leaves, roots, or stems. Common vegetables like carrots, onions, spinach, tomatoes, cucumbers, and broccoli are excellent sources of essential nutrients. Vegetable soup is often consumed for its health benefits, especially by patients with difficulty consuming solid foods due to certain obstructive or pathological conditions. Beyond its nutritional value, people increasingly seek healthy lifestyle choices and foods rich in bioactive components. Vegetable soup is an ideal source of beneficial nutrients that can help reduce the risk of nutrient deficiencies (Küster and Vila, 2017).Vegetable soup is an excellent substitute for people seeking variety and needing high-fiber, low-fat options to support good health. The growing number of women in the workforce has increased demand for convenient food

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sources, including ready-to-eat snacks and easy-to-prepare meals with a strong nutritional profile (Thara and Nazni, 2018). For those following a vegan diet, including protein sources like legumes, cereals, and mushrooms, there's a lower risk of cardiovascular and metabolic disorders. Quinoa (Chenopodium quinoa Willd.) is an ancient grain that has gained recognition for its nutritional benefits, particularly its high-quality protein content, good amino acid profile, and presence of polyunsaturated fatty acids. Quinoa protein content varies from 12.9% to 16.5%, with a high biological value (73%) (Jannat et al., 2018). Additionally, quinoa seeds are gluten-free and rich in minerals, fiber, and vitamins (Pereira et al., 2019). Both chia and quinoa are important traditional crops with superior nutritional qualities. While chia seeds (*Salvia hispanica*) have a high content of dietary fiber, calories, fats, minerals (calcium, magnesium, iron, phosphorus, and zinc), and vitamins (A and B complex), quinoa is recognized for its high and high-quality protein content and nine essential amino acids that are vital for an individual's development and growth. A well-known feature of chia seeds is their high concentration of omega-3 fatty acids. Due to their bioactive compounds, which help fight a variety of chronic diseases like diabetes, obesity, cardiovascular disease, and metabolic diseases like cancer. Quinoa and chia seeds are both gluten-free and have therapeutic qualities. Quinoa seeds contain phenolic compounds, especially kaempferol, which may have anticancer properties. Supplementing quinoa and chia seeds in varying amounts can improve the nutritional profile of a wide range of food products, including meat products and extruded snacks. Additionally, it draws attention to the value-added goods that can be created by combining or using quinoa and chia seeds separately (Agarwal et. al 2023). Based on the above-mentioned report, the aim of the present study is to produce different vegetable soup powders supplemented with two sources of vegetable proteins (quinoa and chia seeds) to enhance their nutritional values.

2. Materials and Methods

Materials

Quinoa, chia seeds, carrots, potatoes, broccoli, salt, and spices used in this study were purchased from a local market in Cairo, Egypt. All chemical reagents were of analytical grade and obtained from El-Gomhoria Co., Cairo, Egypt.

Preparation of Quinoa Seed Flour

Quinoa seeds were thoroughly rinsed with tap water to remove any residual saponins, then dried in an air-drying oven at 60 ± 3°C for 12 hours or until their moisture content reached approximately 10%. The dried seeds were subsequently ground into particles that could pass through a 20-mesh sieve, sealed in plastic bags, and stored in a cool place (4 ± 1°C).

Preparation of Chia Seed Flour

Chia seeds were cleaned by removing foreign matter and grinding them into particles that could pass through a 20-mesh sieve. The ground chia seeds were then packaged in plastic bags and stored under refrigerated conditions (4 ± 1°C).

Preparation and Formulation of Soup Powder with Quinoa and/or Chia Seeds Flour

Carrots, potatoes, and broccoli were washed, peeled, and diced. Quinoa seeds were soaked in water for 24 hours, then rinsed thoroughly to remove saponins. All vegetables, along with quinoa or chia seeds, were combined and blanched in 60 mL of water per 100 grams of soup mix for approximately 15 minutes. The mixture was immediately cooled before being blended with an electric blender. The resulting puree was dried in a ventilated oven dryer at 60-65 °C until completely dry. The dried powder was then ground, milled, and vacuum-packed in sealed glass jars.

Quinoa or chia seeds were added in three different ratios: 30% of each seed, 50% of each seed, and a mixture of 25% quinoa and 25% chia seeds (Formula 5). In one formula, 50% of the potatoes were replaced with the seed mixture, as shown in Table 1.

Table 1 explain the composition of the soup ingredients used and the substitution of chia seeds and quinoa in different proportion for potatoes.

Table 1. Proportion of various ingredients used in different of vegetables soup powder (g/100g)

Formula	Salt	*Spices	Potato	Carrot	Broccoli	Quinoa	Chia
Control	2	2	50	43	3	----	----
30%Q	2	2	20	43	3	30	-----
50%Q	2	2	---	43	3	50	-----
30%CH	2	2	20	43	3	-----	30
50% CH	2	2	--	43	3	-----	50
50%Q+CH	2	2	==	43	3	25	25

* Spices content of (dried onion powder 1.5 gm , black pepper 0.3gm and cardamom 0.2gm)

Chemical Analysis

Moisture, protein, ash, fat, and minerals were determined according to the methods outlined in the AOAC (2016) official methods. Total carbohydrates were calculated by difference using the formula described by Abd El-latif (1990) (Equation 1):

% carbohydrates = 100 - (moisture + protein + ash + fat) (Eq. 1)

Determination of Antioxidant Activity

The total antioxidant activity of the samples was measured in extracts through the evaluation of the free radical scavenging effect on the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical, following the method of Hsu et al. (2003). The antioxidant activity was calculated as follows (Equation 2):

Antioxidant activity (%) = ((A_{517} control - A_{517} sample) / A_{517} control) × 100 (Eq. 2)

Determination of Total Phenolic Content

Total phenolic content was determined according to the method of Zielinski and Kozolowska (2000).

Determination of Flavonoid Content

Flavonoid content was measured according to the method described by Pavun et al. (2018).

Color Index

The color index was determined using the method of Ranganna (1979).

Color Parameters

The color parameters (*L**, *a**, and *b**) of soup powders (control and all formulas) were measured using a LabScan II model Hunter spectrophotometer under illuminant D65. The calculations for these parameters were based on the method of Stintzing et al. (2003). All analyses were performed in triplicate.

Rehydration Ratio

The rehydration ratio was determined following the method of Krokida and Kouris (2003).

Bulk Density (BD)

Five grams of the material were added to a 10 mL graduated measuring cylinder. The bulk density was calculated by dividing the mass of the mixture by the volume occupied in the cylinder (Yetismeyen and Deveci, 2000).

Water Activity (aw)

The water activity (aw) of the dried vegetarian soup mixtures was measured using a Rotronic Hygrolab 3 CH-8303 instrument from Switzerland, as described by Cadden (1988).

Solubility

One gram of the mixture was dispersed in 100 mL of distilled water and centrifuged for five minutes at 3000 rpm. The mixture was then blended at high speed (13,000 rpm) for five minutes. A pre-weighed aluminum dish was filled with a 25 mL aliquot of the supernatant and placed in an oven at 105 °C for five hours. The sample weight was recorded hourly for the following two hours of the drying process (Chauca et al., 2005).

Rheological Properties of Vegetable Soup Samples

Using a Rheotester 2 (Medingen, Germany), 10% sample suspensions were prepared according to Abdelhaleem and Omran (2014).

The suspensions were analyzed using an S cylinder and S2 spindle, subjected to a shear rate range of 1 to 457 s^{-1} at room temperature. Torque response values were converted to shear stress using the manufacturer's formula.

Sensory Evaluation

After dissolving the soup in hot water (10 g dried vegetable soup mixture / 65 mL hot water), the resulting soup samples were evaluated organoleptically for their sensory qualities, including taste, odor, color, texture, and overall acceptability. A panel of ten individuals from the staff of the Food Technology Institute A.R.C conducted the evaluation using a standardized methodology (Wang et al., 2009).

Statistical Analysis

Results were expressed as mean values with least significant differences (LSD). Data were statistically analyzed for variance using a one-way analysis of variance (ANOVA) according to Armitage and Berry (1987). These calculations were performed using the SPSS software system (version 20).

3. Results and Discussion

Physio-chemical Composition of Raw Vegetables, Quinoa, and Chia Seeds

As shown in Table 2, chia seeds have the highest fat and protein content, with values of 31.08% and 17.48%, respectively (Ciau-Soliis et al., 2014). In contrast, potatoes contain the least amount of fat (0.44%) (Choi et al., 2016), and carrots have the lowest protein content (0.80%) (Chen et al., 2016). The highest carbohydrate content was found in quinoa seeds (67.65%) (Vilcacundo and Ledesma, 2017), followed by chia seeds (41.89%) (Hrnčič et al., 2019), and then potatoes (15.65%) (Raigond et al., 2015). In terms of mineral content, chia seed flour had the highest concentrations of potassium, phosphorus, and magnesium, at 394.13mg, 799.79 mg, and 338mg per 100g, respectively. In comparison, quinoa seeds contained 301.98 mg of potassium, 257.15mg of phosphorus, and 105.38mg of magnesium per 100g. Among the fresh vegetables, potatoes exhibited the highest potassium content (177.83mg/100g) and moderate levels of phosphorus and magnesium (23.17mg and 8.07mg per 100 g, respectively). Both potatoes and broccoli were notable for their high phosphorus content, at 23.17 mg and 22.03 mg per 100 g, respectively, compared to 8.04 mg/100 g in carrots. Quinoa and chia seed flours exhibited low levels of total phenolics and flavonoids, likely due to their high solids content. The phenolic content was 0.33 mg/g for quinoa and 0.39 mg/g for chia, while flavonoid content was 1.02 mg/g and 3.01 mg/g, respectively, for the flours of both seeds. In contrast, broccoli, as a fresh vegetable, was relatively rich in phenolics and flavonoids, with values of 0.22 mg/100 g and 1.08 mg/100 g, respectively, compared to carrots, which contained 0.20 mg/100 g of phenolics and 0.51 mg/100 g of flavonoids. Among the vegetables, potatoes had the highest flavonoid content, at 1.28 mg/100g. Moreover, both potatoes and broccoli demonstrated high antioxidant activity, with values of 91.88% and 89.62%, respectively. The other ingredients showed lower antioxidant levels, ranging from 47.81% to 57.83%. These findings are consistent with those reported by Ninfali and Bacchiocca (2003).

Characteristics of Prepared Soup Mix Samples

As shown in Table 3, the physiochemical characteristics of the prepared soup mix powders were influenced by the addition of quinoa or chia seeds. Soup mixes supplemented with 50% quinoa or chia powder exhibited lower moisture content (8.14% for quinoa and 7.33% for chia) compared to the control soup powder (10.17%), likely due to the lower moisture content of quinoa and chia seeds powders (Table 2). The fat content of the control soup powder was 8.38%. Replacing 30% or 50% of the potato flour with quinoa seed powder increased the fat content to 13.76% and 17.98%, respectively, reflecting the higher fat content of quinoa seeds (4.31%). Substituting potato flour with 30% or 50% chia seed flour substantially raised the fat content of the soup mix to 20.62% and 26.80%. The protein content of the soup mix increased from 10.13% in the control sample to 13.04% with 30% quinoa substitution and 25.90% with 50% chia seed flour substitution, due to the high protein content of quinoa. Other soup samples supplemented with quinoa or chia seed flour exhibited lower ash levels (7.73% to 10.37%) due to the partial or complete absence of ash-rich potato powder in the formulas. The total carbohydrates in the control soup sample were 57.01%, primarily due to the high carbohydrate content of potatoes (15.97%) (Table 2). Substituting 30% of the potato powder with quinoa or chia seeds flour slightly reduced the total carbohydrates to 55.43% and 38.34%, respectively. However, incorporating 50% of these flours resulted in a moderate increase in carbohydrates due to the high carbohydrate content of quinoa (53.11%). Regarding mineral content, the control soup sample displayed the highest potassium content (359.87mg/100g) due to the high potassium content of fresh potatoes (Table 2), which constituted 50% of the soup ingredients. Soup samples substituted with quinoa or chia seeds flours showed lower potassium levels, ranging from 153.23 to 205.11mg/100g. Conversely, soup samples with chia seed powder recorded the highest phosphorus and magnesium contents (77.34 to 85.93mg/100g and 30.49 to 33.72mg/100g, respectively), as chia seeds are rich in these minerals (799.79mg/100g). In contrast, the control soup sample with all vegetable ingredients exhibited the lowest phosphorus and magnesium contents (48.12 and 19.97mg/100g. The rehydration ratio of the control soup sample was 5.08 (Table 3). Substituting potato powder with quinoa and chia seed flours did not significantly affect this value, as the rehydration ratios of all other soup samples ranged between 4.48 and 5.14. High rehydration values are essential for allowing the soup powder components to swell, preventing clumping, and ensuring ease of flowability and swallowing by consumers.

Table 3 also includes the color index results for the soup powders. The control sample had a color index of 0.50, which may be due to the discoloration of potatoes during drying, despite the blanching process applied beforehand. All other soup samples, which involved partial or complete replacement of potato powder in the recipes, exhibited lower color index values, ranging from 0.11 to 0.49.

The physio-chemical characteristics of the obtained soup mix powders align closely with those reported by Abdelhaleem and Omran (2014), Ghandhi et al. (2017), and Upadhyay (2017).

Table 2. Some physio-chemical constituents of raw contents

Components	Potato	Carrot	Broccoli	Quinoa	Chia
Moisture (%)	79.35±0.28^{B}	89.18±0.01^{A}	89.43±0.01^{A}	8.53±0.01^{C}	6.63±0.01^{D}
Crude protein (%)	3.04±0.02^{C}	0.80±0.01^{E}	1.98±0.01^{D}	14.13±0.01^{B}	17.48±0.01^{A}
Fat (%)	0.43±0.02^{E}	0.54±0.02^{D}	0.66±0.03^{C}	4.31±0.01^{B}	31.08±0.01^{A}
Ash (%)	1.21±0.01^{C}	0.82±0.01^{D}	0.73±0.01^{E}	2.51±0.01^{B}	3.62±0.01^{A}
Total carbohydrate (%)	15.97±0.01^{C}	8.66±0.06^{D}	7.20±0.01^{E}	70.52±0.03^{A}	41.19±0.13^{B}
Total phenolic (mg/100g)	0.08±0.01^{D}	0.20±0.01^{C}	0.22±0.01^{C}	0.34±0.01^{B}	0.39±0.01^{A}
Total Flavonoid (mg/100g)	1.28±0.01^{B}	0.52±0.01^{E}	1.07±0.00^{C}	1.02±0.01^{D}	3.02±0.01^{A}
Antioxidant activity (%)	91.86±0.02^{A}	89.62±0.01^{B}	47.82±0.01^{E}	57.82±0.01^{C}	48.73±0.01^{D}
Potassium	177.83	78.02	61.02	301.98	394.13
Phosphorus	23.17	8.04	22.03	257.15	799.79
Magnesium	8.07	3.57	6.09	105.38	338.92

A, B & C: There is no significant difference (P>0.05) between any two means, within the same row have the same superscript letter.

Table 3. Some physio- chemical characteristics of prepared soup mix powders (On wet weight basis)

Component	Control Vegetables Soup	Soup supplemented with quinoa seeds		Soup supplemented with chia seeds powder		Soup supplemented with mix of quinoa and chia seeds powder (25%+25%)
		30%	50%	30%	50%	
Moisture (%)	10.17±0.01^{B}	11.37±0.01^{A}	8.14±0.02^{C}	8.04±0.01^{D}	7.33±0.02^{E}	8.04±0.01^{D}
Crude protein	10.13±0.03^{E}	11.23±0.02^{D}	13.04±0.02^{C}	18.90±0.01^{B}	25.90±0.01^{A}	18.89±0.01^{B}
Fat	8.38±0.02^{E}	13.76±0.03^{D}	17.98±0.01^{C}	20.62±0.01^{B}	26.80±0.01^{A}	20.62±0.01^{B}
Ash (%)	14.30±0.01^{A}	8.20±0.01^{C}	7.73±0.01^{D}	14.10±0.01^{A}	10.37±0.26^{B}	14.00±0.06^{A}
Total carbohydrate	57.01±0.05^{A}	55.43±0.05^{B}	53.11±0.03^{C}	38.34±0.02^{D}	29.60±0.25^{E}	38.45±0.06^{D}
Color index	0.50±0.01^{A}	0.13±0.01^{C}	0.49±0.01^{A}	0.13±0.01^{C}	0.21±0.01^{B}	0.11±0.01^{C}
Rehydration ratio	5.08 : 1^{B}	4.48 : 1^{D}	5.14 : 1^{A}	5.13 : 1^{A}	5.13 : 1^{A}	5.02 : 1^{C}
Minerals (mg/100 g)						
Potassium (K)	359.87	166.08	201.49	153.23	179.43	205.11
Phosphorus (P)	48.12	68.02	76.08	77.34	85.93	71.08
Magnesium (Mg)	199.97	24.02	25.09	30.49	33.72	29.23

A, B & C: There is no significant difference (P>0.05) between any two means, within the same row have the same superscript letter

Antioxidant Components of Soup Mix Powder

Antioxidant and nutraceutical compounds, such as total phenolics and total flavonoids, are essential functional properties in vegetable soup mixes.

Table 4 demonstrates that the control soup mix powder contained total flavonoids in concentrations of 0.76 and 4.7mg/100g, respectively. Carrots and broccoli were the primary sources of phenolics, while potatoes were the primary source of flavonoids in the soup mix. Substituting potato powder with 30% or 50% of chia or quinoa flours increased total phenolics to levels of 0.86 to 2.3mg/100g due to the higher phenolics content of both seeds (0.34 and 0.39 mg/100g, respectively, as shown in Table 2). Similarly, incorporating the same ratios of quinoa and chia flour increased flavonoids to levels of 1.61 to 4.70mg/100g. Table 4 also presents the antioxidant activity of the tested soup mixes. As shown, the antioxidant activity of the control (all vegetables) soup was 86.02%. Partial or total substitution of potato powder with quinoa or chia seeds flour raised antioxidant activity to levels of 87.83% to 93.94%. The highest value (93.94%) was recorded for the soup substituted with 50% quinoa seeds flour. These results align with the findings of Fernandez et al. (2020) and Agarwal et al. (2023).

Table 4. Antioxidant components of dried soup mix powders (On wet weight basis)

Component	Control Vegetables Soup	Soup supplemented with quinoa seeds		Soup supplemented with chia seeds powder		Soup supplemented with mix of quinoa and chia seeds powder (25%+25%)
		30%	50%	30%	50%	
Total phenolics (mg/100 g)	0.53±0.01^{F}	1.23±0.02^{D}	2.23±0.02^{A}	0.86±0.01^{E}	1.46±0.01^{C}	1.87±0.01^{B}
Total Flavonoids (mg/100 g)	0.76±0.03^{F}	2.42±0.01^{D}	2.48±0.01^{C}	1.61±0.01^{E}	2.57±0.02^{B}	4.7±0.01^{A}
Antioxidant activity (%)	86.02±0.07^{D}	87.57±0.29^{C}	93.94±0.02^{A}	87.83±0.02^{C}	90.88±0.05^{B}	91.19±0.35^{B}

A, B & C: There is no significant difference (P>0.05) between any two means, within the same row have the same superscript letter

Some physical properties of vegetable soups substituted with quinoa and chia flours: color Analysis

The color values of the soup mixes were determined using a Hunter Lab colorimeter. The results in Table 5 show the variation in the color attributes of the soup powder formulas, as measured by the Hunter Lab. The control soup sample was characterized by lightness (L^*), redness (a^*), and yellowness (b^*) values of 46.32, 19.51, and 30.37, respectively. Substituting 50% of the potato powder with quinoa and chia seed flours increased the lightness (L^*) of the soup mix to 95.66 and 95.85, respectively. This indicates that the soup was lighter (whiter) than the control, possibly due to the removal of potato powder, which tends to undergo browning and darkening reactions during drying. In contrast, the redness (a^*) of the soup mixes decreased to 11.26 and 10.29, compared to the control's value of 19.51. The yellowness (b^*) of the control soup was 30.37, which increased slightly to between 34.02 and 36.41 in the substituted soups, likely because the carrot content, which remained constant at 43%, contributed to the yellow hue.

Color saturation (chroma, C*) remained relatively constant across all soup samples, ranging from 34.75 to 39.73. The control soup exhibited an orange hue, with a hue value (H*) of 57.28, likely due to the high proportion (50%) of discolored potato powder. When 30% of the potato powder was substituted with quinoa or chia flours, the color shifted to an orange-yellow type, with hue values between 64.05 and 66.41. Complete substitution of potato powder with 50% quinoa and chia seed flours resulted in a yellow hue, with hue values between 72.77 and 79.16.

Table 5. Color values of soups by hunter lab

Formula	L	a	b	C	H
(control)	46.32	19.51	30.37	36.05	57.28
30% quinoa	45.22	16.55	34.02	37.83	64.05
50% quinoa	59.66	11.26	35.43	37.18	72.37
30% chia	48.82	15.90	36.41	39.73	66.41
50% chia	59.85	10.29	33.19	34.75	72.77
50% quinoa +chia	40.77	6.71	35.04	35.67	79.16

Water Activity (aw)

Water activity (aw) refers to the amount of water available in equilibrium to hydrate materials (i.e., water availability). It is one of the most important intrinsic factors used to predict the survival and growth of microorganisms in food. By examining the results in Table 6, it is evident that all water activity values are encouraging, as they fall below the level required for mold growth (< 0.6) and range between 0.44 and 0.57 (Fellows, 2000).

Bulk Density (BD)

Bulk density (BD) affects the ease of packaging, and there is a significant difference between the control and the different soup compositions. The results show that the BD of soups containing chia and quinoa seeds significantly decreased, which is attributed to the composition of the nutrient raw materials (Szulc and Lenart, 2016). As shown in Table 6, BD values ranged from 0.46 to 0.96 g/ml.

Solubility

Solubility measures a compound's ability to dissolve in a solvent at equilibrium, typically in a liquid. In this case, the solubility of the soup mix increased with a higher protein content and rising temperatures. Table 6 illustrates that the solubility of the soup containing 50% quinoa and chia seeds increased from 36.74% at 30°C to 41.55% at 60°C. These results align with findings by Sarkar et al. (2019).

Table 6. Physio-chemical properties of instant soup mix

Formula	a_w	BD (g/mL)	Solubility at (30°C)	Solubility at (50°C)	Solubility at (60°C)
Control	0.44±0.01^{d}	0.96±0.01^{a}	25.84±0.02^{f}	31.45±0.01^{f}	35.69±0.02^{f}
30% quinoa	0.48±0.01^{c}	0.48±0.01^{c}	29.44±0.01^{d}	33.79±0.01^{d}	36.24±0.01^{d}
50% quinoa	0.54±0.01^{b}	0.51±0.01^{b}	31.83±0.01^{c}	35.77±0.01^{c}	37.84±0.01^{c}
30% chia	0.53±0.01^{b}	0.46±0.01c	28.76±0.01^{e}	32.93±0.01^{e}	35.86±0.01^{e}
50% chia	0.46±0.01^{cd}	0.53±0.01b	33.65±0.01^{b}	36.75±0.01^{b}	38.44±0.01^{b}
50% quinoa +chia (25%+25%)	0.57±0.01^{a}	0.53±0.02^{b}	36.74±0.01^{a}	39.44±0.01^{a}	41.55±0.01^{a}

a, b & c: There is no significant difference (P>0.05) between any two means, within the same column have the same superscript letter. (mean±SE)

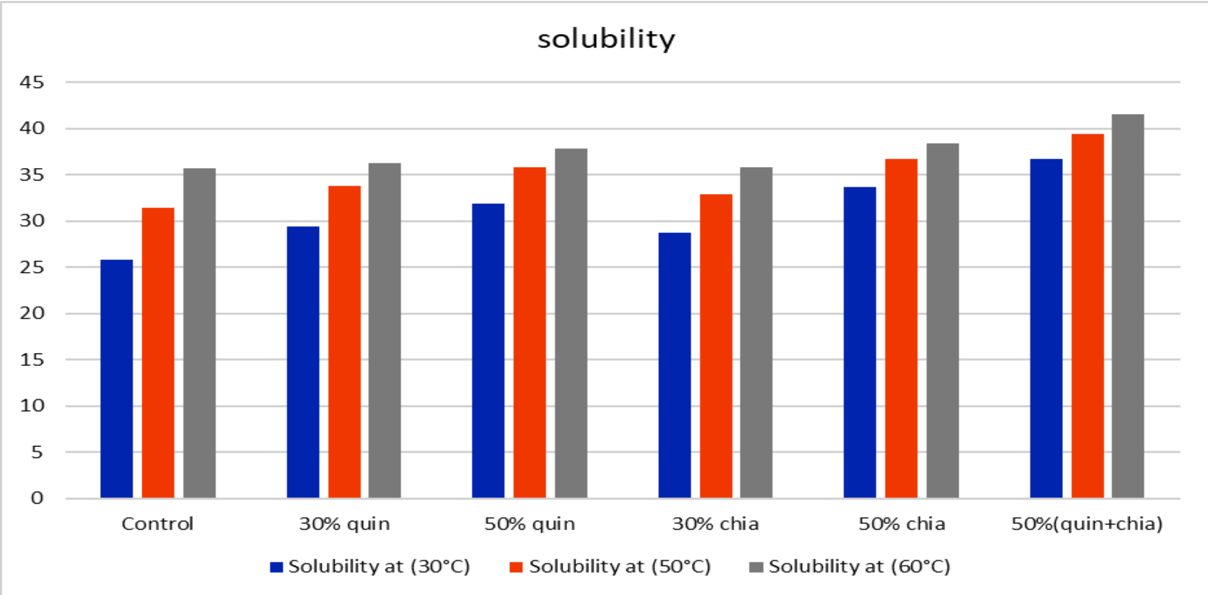


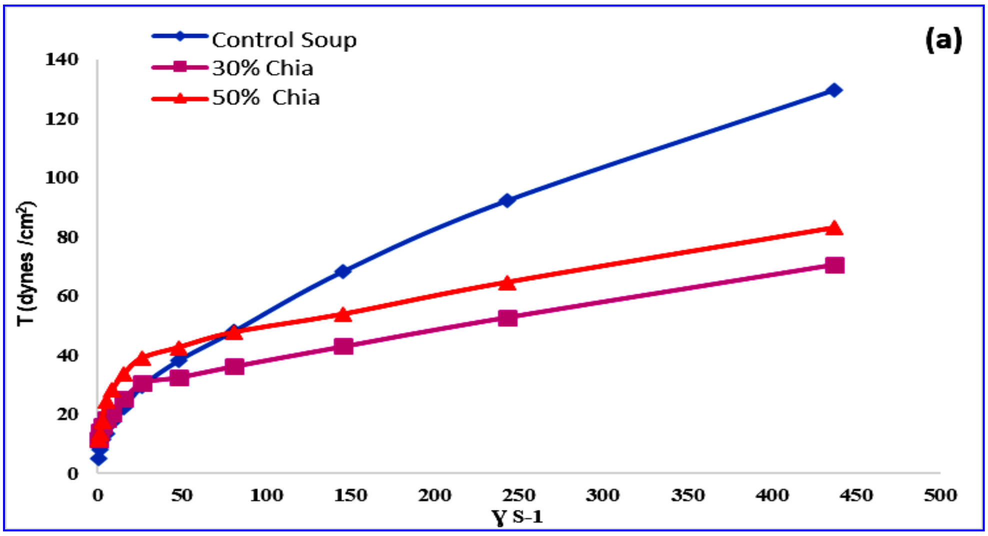
Figure 1. Solubility of vegetable soup powder supplemented with chia and quinoa seeds

Rheological Properties of Vegetable Soups

The rheological properties of the soup samples were measured using a rotational coaxial viscometer at room temperature (20±5°C) over a wide range of shear rates (1 to 437.1 s^{-1}). As described previously, shear stress response (Dynes/cm²) was used to quantify the resistance to deformation. The results are presented in Table 7. The control soup, primarily containing potato and carrot powders, exhibited the lowest shear stress response across all shear rates. This behavior is attributed to its reliance solely on potato starch swelling and gelatinization. The maximum observed value was 129.76 Dynes/cm² (12.98Pa) at a shear rate of 437.1s^{-1}, which aligns with the findings of Abdelhaleem and Omran (2014) for similarly concentrated vegetable soups (≈ 10%).Partial substitution of potato powder with 30% or 50% chia seed flour resulted in a decrease in shear stress values throughout the applied shear rate range. This indicates a lower internal resistance to flow within the soup slurry following the addition of chia seed flour. The observed reduction in shear stress response averaged 40% and 35% for 30% and 50% replacement of potato flour, respectively. This decrease can be attributed to the high fat content (≈30%) of chia seeds and the potential removal of chia seed mucilage during the soaking process. These results are consistent with those reported by Abo-Zaid and Saleh (2020), who observed a 38% reduction in viscosity for a corn flour-potato starch soup mix substituted with germinated chia seed flour. However, the use of 1% pure chia seed mucilage was found to enhance the viscosity of chicken and vegetable puree. Conversely, partial substitution of potato flour with quinoa flour improved the rheological properties of the tested soup samples. The flow resistance, expressed as shear stress response, increased by 58% and 77% upon replacing potato flour with 12.5% and 25% quinoa flour, respectively. According to Ayseli et al. (2020), quinoa flour is highly soluble and possesses a balanced composition of carbohydrates, proteins, lipids, and dietary fibers. Notably, quinoa starch has low amylose content and short-chain amylopectin, which contribute to high binding capacity, swelling, pasting viscosity, and ultimately, a thicker soup texture. Table 7 summarizes the rheological parameters of the tested soups as described by the power-law model (equation 1): $\tau = k\gamma^n$. The control soup (10% slurry) displayed a consistency value (K) of 5.69 Dynes.s^n/cm² (0.57Pa.s^n) and a non-Newtonian flow behavior index (n) of 0.503. Incorporating quinoa flour increased the K-values to 30.39 and 65.29 Dynes.S^n/cm², respectively, for 30% and 50% quinoa substitution. Additionally, it amplified the non-Newtonian character of the soup slurry, as reflected by the reduction in n-values to 0.306 and 0.229, respectively. On the other hand, the inclusion of chia seed flour resulted in moderate increases in K-values (11.59 and 12.83 Dynes S^n/cm²). For a practical comparison between the samples, the apparent viscosity (μa) at a shear rate of 145.8 s^{-1} was calculated using both K and n values ($\mu a = k\gamma^{n-1}$). The results are presented in Table 7. The control soup sample exhibited a viscosity of 478 mPa.s^n (cP), while both chia seed flour formulations displayed lower viscosities (316 and 406 mPa.s). Conversely, the quinoa flour samples demonstrated higher viscosities (957 and 1401 mPa.s). The addition of 25% chia flour and 25% quinoa flour yielded a soup with a viscosity of 1147 mPa.s, closer in value to the quinoa flour samples alone. High viscosity values are generally associated with desired plasticity and consumer acceptance in soups.

Table 7. Rheological parameters of tested vegetables soup samples

Component		Control vegetables soup	Soup supplemented with quinoa seeds		Soup supplemented with chia seeds powder		Soup supplemented with mix of quinoa and chia seeds powder (25%+25%)
			30%	50%	30%	50%	
Consistency coefficient K (Dynes. s^n/cm^2)		5.69	30.39	65.29	11.59	12.83	28.52
Newtonian index n (-)		0.503	0.306	0.229	0.2772	0.307	0.355
R^2 value		0.994	0.971	0.985	0.989	0.976	0.994
Viscosity (μa) at ɣ = 145.8 s^{-1}	Dynes.s/cm^2	0.478	0.957	1.401	0.316	0.406	1.147
	mPa.s	478	957	1401	316	406	1147



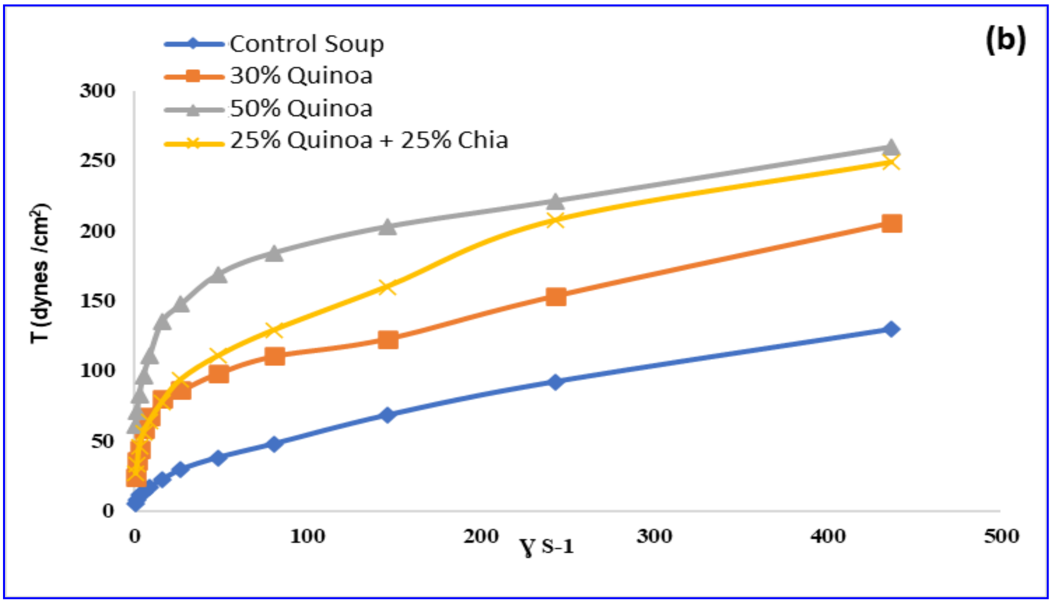


Figure 2. Rheograms of potato carrot flours-based vegetables soup as affected by addition of Chia and quinoa flours

Sensory Characteristics of Vegetable Soup Powder

Data presented in Figure 3 show the results of the sensory evaluation of the prepared vegetable soup powders. Respondents preferred the soup powder supplemented with 30% quinoa seeds, followed by the powder with 50% quinoa seeds, compared to the other soup powders. The control soup powder had sensory evaluation scores similar to those of the soups supplemented with chia seeds (30% and 50%). As shown in Figure 4, the formula containing a mixture of quinoa and chia seeds (25% quinoa + 25% chia) recorded the lowest values across all sensory parameters.

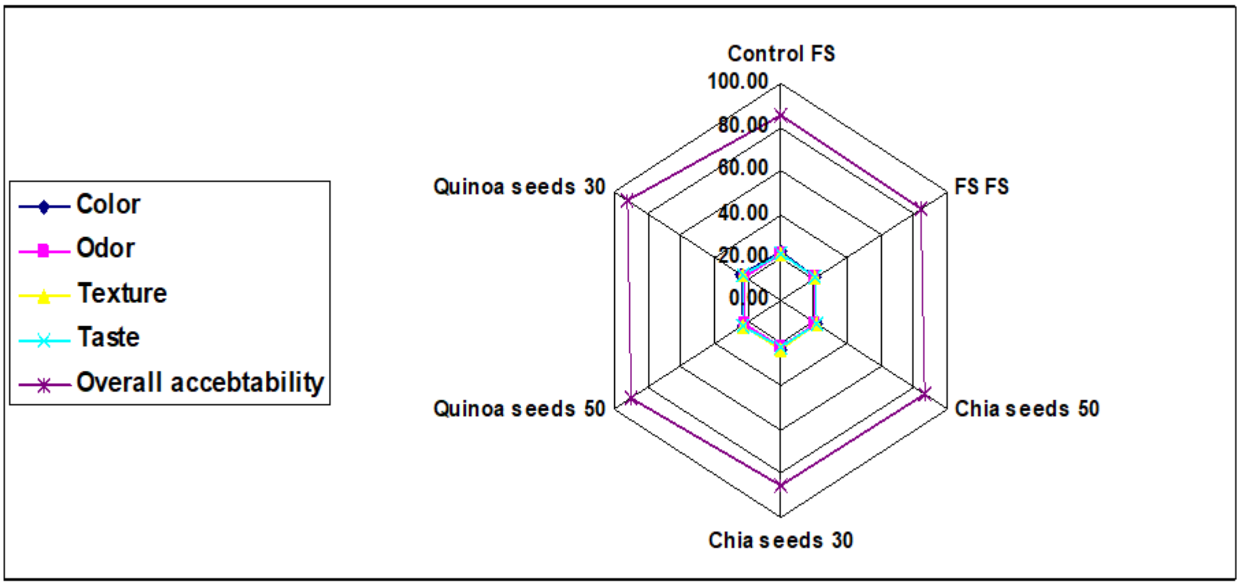


Figure 3. Sensory of characteristics vegetables soup powder

4. Conclusion

The study demonstrated that supplementing vegetable soup powders with quinoa and chia seeds significantly improved the nutritional and functional properties of the soups. The addition of these seeds enhanced the protein, fat, and mineral content, particularly phosphorus and magnesium, while also increasing the antioxidant activity and phenolic content. Substituting potato with quinoa and chia flours resulted in soups with higher lightness and yellowness, while reducing redness, enhancing visual appeal. The bulk density and solubility of the soups were improved, making them more convenient for packaging and consumption. Sensory evaluations revealed that soup powders containing 30% quinoa were the most preferred, with overall acceptability scores higher than other formulations. The mixture of quinoa and chia seeds (25% each) yielded the lowest sensory scores, indicating that balanced incorporation is crucial for optimizing taste and texture. Ultimately, this research highlights the potential for using quinoa and chia to create nutrient-dense, convenient soup products for health-conscious consumers.

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