Quality Properties of Pasta Fortification with legume Flour and Mallow (*Malva parviflora* L.) Leaves Powder

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ABSTRACT

This study aimed to produce pasta fortified with legume flours (7% defatted soy flour and 7% chickpea flour) and mallow (*Malva parviflora* L.) leaves powder at concentrations of 0%, 4%, 8%, and 12%. The rheological properties of the composite dough were examined, along with the chemical composition, texture, color, and water activity of the uncooked pasta samples. Additionally, the cooking quality and sensory attributes of the pasta were evaluated. The results showed that the rheological properties of the composite dough, such as water absorption, dough development time, and arrival time, increased, while dough stability and dough weakening decreased with the addition of legume flours or increased levels of mallow leaves powder. Furthermore, adding legume flours or increasing the mallow leaves powder levels resulted in a gradual increase in protein, ash, fat, fiber, vitamins, and mineral content, while moisture and carbohydrate contents decreased in the uncooked pasta samples. Regarding color, the *L, *a**, and *b** values of the uncooked pasta samples gradually decreased with the addition of legume flour or higher levels of mallow leaves powder. The cooking quality, including weight gain, volume increase, and cooking time, improved, while cooking loss decreased with the addition of legume flours or higher levels of mallow leaves powder. Additionally, all sensory attributes of the pasta samples were acceptable. In conclusion, high-nutritional-value pasta with good quality characteristics can be produced by fortifying it with chickpea flour, defatted soy flour, and mallow leaves powder.**

Keywords: Chickpea, soya, mallow leaves, pasta, color, texture.

INTRODUCTION

Wheat pasta products are the most popular food next to bread. Pasta is generally a cereal-based product that is becoming popular worldwide because of its convenience, low cost, desirable organoleptic properties, long shelf life, ease of preparation, and palatability**.** Pasta products are normally high in starch but low in minerals, vitamins, dietary fiber, phenolic compounds, etc. It is necessary to make them nutrient-rich to produce high-quality pasta to provide a balanced snack/meal (Veena and Shivaleela, 2019). Recently, consumers have demanded healthier food products, and this has meant that composite flours, which are partially substituted or fortified with other natural bioactive ingredients (Ali *et al.,* 2020 and Althwab *et al.,* 2021). The fortification pasta, with legume development of well-balanced protein diets, represents a rich source of amino acids that complements the nutritional value of the functional products (Hoehnel *et al.,* 2022). Also, pasta with added plants, vegetables, fruits, and legumes contains a variety of essential nutrients, such as phytochemicals, fiber, vitamins, polyphenols, carotenoids, glucosinolates, and minerals that are influenced by various quality attributes such as physical, chemical, texture, nutritional, taste, flavor, and cooking properties (Soni and Kumar, 2021).

The herbal remedies are used in the normal and daily diets of humans and animals due to their high nutritional value and biological functions, some of them such as the mallow plant (Ameer and Alkassar, 2023). *Malva parviflora* L. is a leafy vegetable belonging to the family Malvaceae. It is an edible and medicinal herb, and it is an annual or perennial herb native to Northern Africa. The common names include cheeseweed, mallow, and little mallow (Raheem *et al.,* 2014). In Egypt, the popular name is Khobeza (Islam *et al.,* 2010). It has also been used as food for humans and animals (Rasheed *et al.,* 2017). The raw leaves are usually added to salads and used in different ways as spices, flavouring agents and garnishes or eaten in the cooked form (Bhawana & Neetu, 2015 and Messaoudi *et al.,* 2015). Furthermore, leaves are rich in protein, carbohydrates, soluble fibers, terpenoids and pigments (Messaoudi *et al.,* 2015). It is also, a potential source of mucilage as a hydrocolloid that are polysaccharide that has functional properties, including stability, emulsion stability, emulsion and foaming capacity, which increased with increased concentrations (Munir *et al.,* 2021 and Altyar *et al.,* 2022).

Legumes such as chickpeas, soybeans, lupine, and peas are characterized by their high nutritional value, as they are rich in protein, low in fat, high in dietary fiber, and a good source of micronutrients and phytochemicals. Composite flour legumes and wheat

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flour are used in the production to enhance the healthy, nutritional and functional benefits (Maray, 2023), but have effects on the functional and viscoelastic characteristics of wheat flour dough (Giménez *et al.*, 2012 and Gliguem *et al*., 2022). Moreover, chickpeas (*Cicer arietinum* L.) are the second most consumed legume in the world, second only to soybeans. Chickpeas contain a large number of bioactive compounds (Kumari, 2023 and Delgado-Andrade *et al***.,** 2024). Also, defatted soy (*Glycine* max) flour is a potential source of protein, amino acids, ash, and isoflavones (Kang *et al***.,** 2017). So, legumes can alleviate many diseases, such as diabetes and its related metabolic complications (Das *et al*., 2022). Increasing the level of dietary fiber and reducing the glycemic index of pasta (Almanza-Benitez *et al.,* 2015).

Therefore, the present study was carried out to produce composite wheat flour containing legumes and mallow leaves, study the rheological properties of dough and study the chemical composition, and physical characteristics of pasta samples as well as water activity cooking quality, textural, color and sensory properties.

MATERIAL AND METHODS

Wheat flour (72%), peeled roasted chickpeas (*Cicer arietinum* L.), brought from the local market of Mansoura city. Defatted soy *(Glycine max)* flour was obtained from the Food Technology Research Institute, Agricultural Research Center, Giza, Egypt. Fresh mallow leaves (*Malva parviflora*) were collected from plants in the governorate of Mansoura, Dakahelia, Egypt, in the floral physiological stage during February and March 2023.

Preparation of mallow leaves and composite flour

Mallow leaves (*Malva parviflora*) were separated from the stems and washed, dried by air at room temperature, and shade-dried for 20 days. Then, the dried leaves were milled. Peeled roasted chickpea was milled by a house mincer. Composite flour was prepared by replacing wheat flour with legumes (defatted soy and chickpea) and mallow leaves powder, as mentioned in Table (1). All dried materials were passed through a sieve (10 mesh) thrice to improve mixing and stored in a polyethylene bag at 4 °C until used in pasta preparation and analysis.

Preparation of pasta samples:

Pasta samples were prepared according to Mostafa (2017). All dried materials and oil as found in Table (1) mixed by using a dough mixer (Kitchen Aid Professional 600, MI, USA) for 2 mins. Warm water (55-70 ml) at 32–49 °C was slowly added and kneaded for 20 min. The dough was wrapped in plastic film and set to rest at room temperature for 1/2 h. After that, the dough was divided into 2 pieces. Each dough piece was flattened through the pasta machine (Imperia Tipo Lusso SP150, Torino, Italy) at thicknesses (numbers 1, 2, 3, and 4, respectively). The thin, flattened sheets were laid to dry for 10 minutes before being passed through the fettuccine cutter. The cut strands were laid on wire racks and covered with a towel to dry overnight. The dried pasta was stored in polyethylene bags at room temperature until further analysis.

Chemical analysis

The chemical composition of protein, moisture, fat, ash, and cured fiber was determined according to AOAC (2010). Total carbohydrates were calculated.

as following: carbohydrate% = 100 - (moisture% + protein% + fat%+ ash%).

Vitamins such as (β-carotene, thiamin, riboflavin, pyridoxine, folic acid, and vitamin C) and minerals such as magnesium, phosphor, potassium, calcium, iron, and zinc were determined according to AACC (1983).

Rheological properties of dough composite flour

Rheological properties of dough composite flour were evaluated by using a farinograph according to AACC (2000).

Table 1. Formula of pasta samples

Ingredients	Composit flour			Other ingredients		
	Wheat flour	Chickpea flour	Defatted Soy flour	Mallow leaves powder	Salt	Sunflower oil
PC	94	-	-	-	1.5	4.5
MLP1	80	7	7	-	1.5	4.5
MLP2	76	7	7	4	1.5	4.5
MLP3	72	7	7	8	1.5	4.5
MLP4	68	7	7	12	1.5	4.5

PC: pasta contains 0% Legumes and 0% mallow powder. MLP1: pasta contains legumes (7% chickpea and 7% Defatted Soy flour) 0% mallow powder MLP2: pasta contains legumes and 4% mallow leaves. MLP3: pasta contains legumes and 8% mallow leaves powder. MLP4: pasta contains legumes and 12% mallow leaves powder.

Physical characteristics

Texture profile analysis (TPA) of uncooked pasta samples as hardness, cohesiveness, gumminess, elasticity, chewiness, and adhesiveness parameters were evaluated with a TA-XT2i Texturometer (Stable Micro System, Godalming, UK). All samples were prepared and analysed according to the AACC-approved method 66-50.01 (AACC, 2000).

The color of the uncooked pasta was recorded using Konica Minolta CR-400 Chromameter (Japan) as described by Veena and Shivaleela (2019).

Water activity (^{a}W) of uncooked pasta was measured using a precalibrated water activity meter (AquaLab LITE, Aqualab, Washington, USA), as described by Kaur *et al.* (2012).

Cooking quality as cooking loss, weight increase (%), volume increase (%), and cooking time of pasta samples were measured as described by Veena and Shivaleela (2019).

Sensory evaluation of pasta samples

The sensory properties of pasta samples were calculated after cooking in water up to optimum cooking time (5-8 min), allowed to infuse until they absorbed water, rested for two minutes, and then analyzed. The sensory valuation was evaluated by 20 semi-trained panel members from the Department of Home Economics, Faculty of Specific Education, Aswan University, according to the method of Rekha *et al.* (2013). Cooked pasta samples were evaluated by scoring 7 sensory properties: color, taste/flavor, odor, appearance, stickiness, mouthfeel, and general taste.

Statistical analysis

A statistical program for social science (SPSS), version 17.00, SPSS Inc., Chicago, IL, USA, using at the 0.05 level. The averages and standard deviations (SD) of the research results were reported. For continuous variables, data were analyzed using a one-way analysis of variance (ANOVA). Per SPSS (2008). A P value under 0.05 was deemed as statistically significant.

RESULTS AND DISCUSSION

The chemical composition of raw materials:

Data in Table (2) showed that the chemical composition of mallow (*Malva parviflora*) leaves powder, wheat flour, legumes flour (defatted soy and chickpea). Wheat flour had the highest moisture content, followed by defatted soy flour. Also, defatted soy flour had the highest content of protein, followed by chickpea flour, mallow flour, and wheat flour, respectively. Furthermore, chickpea flour has the highest content of fat, followed by mallow powder, defatted soy flour, and wheat flour respectively. Furthermore, chickpea flour has the highest content of fat, followed by mallow powder, defatted soy flour, and wheat flour, respectively. Mallow powder has the highest contents of ash and fiber, followed by defatted soy flour, chickpea flour, and wheat flour, respectively. Also, wheat flour has high content of carbohydrates followed by mallow powder, chickpea and defatted soy flour respectively. The chemical composition of wheat flour and mallow leaves is in agreement with those of Mohammed *et al.* (2023) they found that the chemical composition of wheat flour was 10.56, 11.24, 0.90, 1.12, 0.53, and 86.21; also, the chemical composition of mallow (*Malva parviflora*) leaves (on a dry weight basis) was 6.90, 23.95, 3.65, 10.13, 9.87, and 52.40 moisture, protein, fat, ash, and carbohydrates, respectively. The chemical composition of defatted soy flour agrees with that of Bashir *et al.* (2012) and Okafor & Ebuehi (2016). Also, the results of the chemical composition of chickpea flour were in agreement with those of Abd Rabou (2017) and Mohamed *et al.* (2022).

Table 2. The chemical composition of raw materials

Parameters / Samples	Moisture%	Protein%	Fat%	Ash%	Carbohyrate%	Fiber%
wheat flour	10.56±0.31a	11.24±0.46d	0.90±0.10d	1.12±0.11d	76.18±0 0.38 a	0.53±0.06d
MLP	7.02±0.13c	23.81±0.25c	3.72±0.19b	9.92±0.07a	55.53 ± 0.19 c	10.15±0.15a
Defatted soy flour	9.60±0.17b	47.90±0.96a	2.70±0.17c	6.30±0.20b	33.50 ±1.23d	4.07±0.21b
Chickpea flour	7.50±0.30c	33±1.73b	4.20±0.20a	3.21±0.09c	52.09 ±1.87b	2.60±0.26c
P<	****	****	****	****	****	****

MLP: mallow leaves powder. means. (a, b, c and d): means within the same column differ significantly at p<0.05 when accompanied by a different superscript. * P<0.05; ** P<0.01. *** P<0.001. **** P<0.0001.

Rheological properties of dough:

Data in Table (3) shows the rheological properties parameters as water absorption, dough development time and arrival time of composite flour as replacement wheat flour by legume flour (7.5% defatted soya and 7.5% chickpea) or 4, 8 and 12% mallow leaves powder. The result showed that the water absorption, dough development time, and arrival time were increased, but dough stability (min) and dough weakening (BU) were decreased as fortification composite flour with defatted soya and chickpea flour or by increasing levels of mallow leaves powder. The result of increasing water absorption as a result of fortifying composite with defatted soya and chickpea flour was due to increased levels of fiber and protein content. This result was due to an increase in the mixture's ability to absorb water due to their protein fractions, such as globulins, which interact with gluten protein in the dough. This result is similar to that of Bayomy and Alamri (2022).

Decreasing dough stability and increasing development time and arrival time indicate the weakness of dough strength of pasta fortification with legume flour.This result might be due to the dilution of gluten. There may be competition between gluten and legume proteins added to the water delaying the hydration process. The observed effects of delaying dough development and stability times. This result agrees with those of Ribotta *et al.* (2005) and Bayomy & Alamri (2022). Moreover, ur Rehman *et al.* (2018) found that increasing levels of chickpea and soybean flour caused an increase in water absorption with a concurrent decrease in development and dough stability times due to the lower gluten content.

The result of the gradual increase water absorption as increasing levels of mallow leave powder in pasta samples were due to increasing protein and fiber that could absorb water. This result agrees with that of El-Refai *et al*. (2021), who found the addition of either moringa or turmeric powder recorded the highest value of water absorption on pan bread. Also, gradually decreasing dough stability and increasing development time and arrival time indicate the weakness of dough strength of pasta as increasing levels of mallow leaves powder. This result may be attributed to the dilution effect of gluten. This result agrees with that of Abd El-Ghany (2020), who found that increasing moringa in composite flour caused a decrease in stability time, which indicates the weakness of dough strength.

The chemical composition of pasta samples

Data in Table (4) shows the chemical composition of pasta samples. The moisture and carbohydrate contents were decreased, but the ash, fat, protein, and fiber contents of pasta were increased as fortification with defatted soya and chickpea flour. This result is because defatted soya and chickpea flour had high contents of ash, fat, protein, and fiber compared to wheat flour. This result of fortification with chickpea flour agreed with that of Bayomy and Alamri (2022), who indicated that the enhanced instant noodles with chickpeas caused a significant increase in protein, fat, ash, and crude fiber contents. Furthermore, this result agrees with that of Bhatt *et al*. (2015), who found that fortification of pasta with different pulses such as chickpea flour, red lentil flour, white lentil flour, green gram flour, and soy flour causes significant increases in the protein, fat, sugar, and fiber content of the final product, while the carbohydrate content of prepared pulse pasta decreased in comparison to control pasta.

Table 3. Rheological properties of dough samples

Samples	Water absorption (%)	Arrival time (min)	Dough development time(min)	Dough stability (min)	Mixing tolerance index (BU)	Dough weakening (BU)
PC	58.2	1.9	2.1	13.7	40	60
MLP1	65.5	2.1	2.20	12.9	55	70
MLP2	79	2.7	2.5	11.0	60	80
MLP3	82	3.0	2.7	9.0	65	90
MLP4	85	3.5	3.1	8.3	70	105

PC: pasta contains 0% Legumes and 0% mallow powder. MLP1: pasta contains legumes (7% chickpea and 7% Defatted Soy flour) 0% mallow powder MLP2: pasta contains legumes and 4% mallow leaves. MLP3: pasta contains legumes and 8% mallow leaves powder. MLP4: pasta contains legumes and 12% mallow leaves powder

Table 4. The chemical composition of pasta samples

Parameters / Samples	Moisture%	Protein%	Fat%	Ash%	Carbohyrate%	Fiber%
PC	12.25±0.23a	10.0±0.20d	3.21±0.10b	2.08±0.07e	72.46±0.12a	o.91±0.09e
MLP1	12.01±0.29ba	14.23±0.26c	3.3±0.20ba	2.96±0.10d	67.5±0.49b	2.07±0.20d
MLP2	11.63±0.23bc	15.16±0.20b	3.4±0.10ba	3.53±0.06c	66.28±0.07c	2.83±0.06c
MLP3	11.21±0.09dc	16.69±0.27a	3.5±0.10ba	4.19±0.04b	64.41±0.29d	3.69±0.10b
MLP4	11.09±0.09d	17.13±0.15a	3.58±0.11a	4.96±0.05a	63.24±0.05e	4.27±0.06a
P<	****	****	*	****	****	****

PC: pasta contains 0% Legumes and 0% mallow powder. MLP1: pasta contains legumes (7% chickpea and 7% Defatted Soy flour) 0% mallow powder MLP2: pasta contains legumes and 4% mallow leaves. MLP3: pasta contains legumes and 8% mallow leaves powder. MLP4: pasta contains legumes and 12% mallow leaves powder Each analysis is the average of three replicates. SEM: Standard Error of means. (a, b, c d and e): means within the same column differ significantly at p<0.05 when accompanied by a different superscript. * P<0.05; ** P<0.01. *** P<0.001. **** P<0.0001.

In the same table, fortification pasta with 0, 4, 8, and 12% mallow leaves powder caused a gradual increase in protein, fat, ash, and fiber contents, and gradually decreased in moisture and carbohydrate contents as increasing levels of mallow leaves powder. So, pasta with 12% mallow leaves powder had the highest contents of protein, fat, and ash and the lowest carbohydrates compared to other pasta samples. All these results are in agreement with those of Mohammed *et al*. (2023), who found that the incorporation of bread with different mallow leaves powder caused an increase in nutritional value. Furthermore, Hammad and Abo-Zaid (2020), found that the incorporation of pasta with different levels of turnip leaf powder caused an increase in protein, fat, and ash and a decrease in carbohydrates; and Khojah *et al.* (2017), found that fortification of instant noodles with broccoli caused an increase in its chemical composition.

Mineral contents of pasta samples

The ash content of food is widely used as a quality indicator for evaluating its functional qualities and related to the food’s mineral composition (Mohammed *et al*., 2023).

Data in Table (5) showed the mineral contents of mallow leaves powder, wheat, and its mallow pasta samples. The mallow leaves had a significantly higher concentration of macro- and micronutrient minerals such as phosphorus, potassium, calcium, magnesium, sodium, iron, manganese, and zinc compared to those of wheat flour. This result agrees with those of Mohammed *et al*. (2023). Also, Abdalla *et al.* (2016) reported that the *mallow parviflora* is a good source of macro and microelements. The minerals P, K, Ca, Mg, and Na of pasta samples were increased, but iron, manganese, and zinc were decreased as fortification pasta with legumes. This result agrees with Hegazy *et al.* (2009), who found that the mineral content of tortilla chips fortified with leguminous flours such as defatted soy flour and chickpea was extremely high as compared with control.

Table 5. Minerals content of pasta samples, mg /100g

Parameters / Samples	Phosphorous (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Iron (Fe)	Manganese (Mn)	Zinc (Zn)
wheat flour	120.94	3.83	20.760	10.07	9.57	6.79	2.22	0.05
MLP	42.85	906	226.5	181.5	33.4	15.04	23.12	83.6
PC	236.176	104.66	16.43	41.18	14.70	4.39	0.29	0.85
MLP1	227.89	140.90	25.49	48.44	16.04	5.00	1.22	4.20
MLP2	219.60	177.86	36.45	55.46	17.94	5.06	2.14	7.45
MLP3	215.32	211.81	46.40	63.48	19.15	5.11	3.06	10.64
MLP4	212.03	248.77	55.36	68.50	20.35	5.16	3.93	13.81

PC: pasta contains 0% Legumes and 0% mallow powder. MLP1: pasta contains legumes (7% chickpea and 7.5% Defatted Soy flour) 0% mallow powder MLP2: pasta contains legumes and 4% mallow leaves. MLP3: pasta contains legumes and 8% mallow leaves powder. MLP4: pasta contains legumes and 12% mallow leaves powder Each analysis is the average of three replicates

Moreover, phosphorus was decreased, but K, Ca, Mg, Na, Fe, Mn, and Zn mineral content of pasta samples was gradually increased as levels of mallow were increased. This result agrees with that of Mohammed *et al*. (2023), who found that supplementation of wheat bread with *mallow parviflora* leaves resulted in significant increases in the mineral content of fortified breads. In addition, Waseem *et al.* (2021) found that wheat flour enrichment with spinach powder (20%) increased the content of micro and macrominerals in composite flour chapattis.

Vitamin contents of pasta samples

Data in Table (6) shows the vitamin contents of mallow leaves, wheat flour, and pasta samples. The result of thiamin (B1), riboflavin (B2), pyridoxine (B6), folic acid (B9), and cobalamin (B12) of mallow leaves powder was more than that of white wheat flour. The result of vitamin of mallow leave powder is in agreement with that of Ali *et al.* (2024). Moreover, β-Carotene of mallow leaves agreed with this of Fakhfakh *et al.* (2017) who found that β-Carotene of mallow leaves is 50 mg/kg. Also, the result of the vitamin content of wheat flour is in agreement with that of Kumar *et al.* (2011). Also**,** Saleh and Ali (2020) reported that since wheat flour is approximately free of β-carotene and vitamin C. Pasta's vitamin content increased as adding legumes and gradually increased as the level of mallow was increased. All these results agree with those of Hammad and Abo-Zaid (2020) who found that incorporating pasta with turnip leaves powder in the noodles formulas could improve the nutritional quality of the noodles.

Water Activity of pasta samples

The quality of foods refers first to safety and then to sensory and nutritional properties. Water activity is more important to the stability of food than the total amount of water present, and it makes it possible to develop generalized rules or limits for the stability of foods (Bonazzi and Dumoulin, 2011).

Data in Table (7) showed that the water activity in pasta samples ranges between 0.401 to 0.454. The recommended level of water activity is 0.5 for pasta (Manthey *et al.,* 2008). Also, the water activity of uncooked pasta samples was decreased as fortification with legume flour and was gradually decreased with increasing levels of mallow leaves powder. This result was due to a decrease in moisture as found in Table (4), so decreasing water activity of dry pasta generally leads to an increase in the shelf life. So, pasta samples can be stored for several months in an airtight container. The result was agreed with that of Bonazzi and Dumoulin (2011). Moreover, the result of pasta fortification with mallow leaves agreed with that of Barcelon *et al.* (2015), who found that fortification of pasta with vegetables caused a decrease in moisture and water activity.

Table 6. Vitamins content of pasta samples, mg /100g

Parameters / Samples	β-Caroten b	Thiamin (B1)	Riboflavin (B2)	Pyridoxine (B6)	Folic (B9)	Vitamin C
MLP	50.15	5.62	67.52	9.31	25.68	6.49
wheat flour	0.276	0.10	0.03	-	0.031	1.00
PC	0.25	0.09	0.03	0.00	0.03	0.90
MLP1	6.23	0.14	0.07	0.22	37.53	1.19
MLP2	8.24	0.36	2.77	0.59	38.55	1.45
MLP3	9.41	0.16	5.46	0.96	57.52	1.29
MLP4	11.00	0.17	8.16	1.34	67.52	1.34

PC: pasta contains 0% Legumes and 0% mallow powder. MLP1: pasta contains legumes (7% chickpea and 7.5% Defatted Soy flour) 0% mallow powder MLP2: pasta contains legumes and 4% mallow leaves. MLP3: pasta contains legumes and 8% mallow leaves powder. MLP4: pasta contains legumes and 12% mallow leaves powder Each analysis is the average of three replicates

Table 7. Water Activity of uncooked pasta samples

Samples	PC	MLP1	MLP2	MLP3	MLP4	P<
Water Activity	0.52±0.02a	0.454±0.01b	0.431±0.01cb	0.422±0.00cb	0.401±0.01c	****

PC: pasta contains 0% Legumes and 0% mallow powder. MLP1: pasta contains legumes (7% chickpea and 7.5% Defatted Soy flour) 0% mallow powder MLP2: pasta contains legumes and 4% mallow leaves. MLP3: pasta contains legumes and 8% mallow leaves powder. MLP4: pasta contains legumes and 12% mallow leaves powder Each analysis is the average of three replicates. SEM: Standard Error of means. (a, b, and c): means within the same column differ significantly at p<0.05 when accompanied by a different superscript. * P<0.05; ** P<0.01. *** P<0.001. **** P<0.0001

Texture of uncooked pasta samples

The texture is very important in the determination of final acceptance by consumers, and this is one of the predominant criteria for evaluating the quality of pasta (Espinosa-Solis *et al.*, 2019 and Axentii *et al*., 2023).

Data in Table (8) showed that the texture of uncooked pasta samples as hardness, gumminess, elasticity, chewiness, and adhesiveness of pasta was increased, but the cohesiveness was decreased as fortification with legume flour or gradually increased levels of mallow leaves powder. The hardness increase may be due to increasing levels of protein contents that cause an increase in strength and elasticity; this result was in agreement with that of Jalgaonkar *et al.* (2018), who found that pasta texture depends to a great extent on the presence of a tough protein network. The result of the texture of pasta fortification with legumes (soya flour and chickpea) was in agreement with that of Chepkosgei and Orina (2021); also, Espinosa-*Solis et al.* (2019), who found that the cohesiveness of pasta gradually decreased but adhesiveness was increased. This suggests changes in the texture quality of the pasta, and it could be used to know the possible acceptability of the product by consumers. These results indicated that pasta fortification with legumes and mallow leaves powder had good quality, this result agrees with that of Udachan and Sahoo (2017), who reported that the primary parameters are hardness, springiness, and cohesiveness, which should be higher, whereas the secondary parameters are chewiness and resilience.

Color of uncooked pasta samples

Data in Table (9) indicated that color (*L**, *a**, and *b**) values of pasta control had the highest lightness L*, a* greenness brightness, redness and yellowness parameter compared to pasta fortification with legume flour (7.5% chickpea and 7.5% defatted soy) or were gradually decreased as increasing levels of mallow powder. The result of the decrease might be due to an increase in ash and dietary fibre and polyphenols contents as fortification with legume flour or mallow powder. The result of adding legumes flour agreed with that of Ugarčić-Hardi *et al.* (2007) and Chepkosgei and Orina (2021), who reported that pasta samples were fortified with defatted soy flour and wheat straw had the lowest L* values (higher brownness), bright yellow (higher b* values), and lower a* which can be explained by the higher content of ash and dietary fibre.

Table 8. Texture of uncooked pasta samples

Samples	Hardness	Cohesiveness	Gumminess	Elasticity	Chewiness	Adhesiveness' (N × m) 1 × 10−9
PC	63.5	0.72	30.5	1.01	0.42	89
MLP1	70.21	0.61	35	1.25	0. 5	120
MLP2	76.81	0.45	39.2	1.44	0. 57	198
MLP3	79.21	0.41	43.1	1.67	0.61	289
MLP4	85.7	0.39	48.9	1.89	0.63	375

PC: pasta contains 0% Legumes and 0% mallow powder. MLP1: pasta contains legumes (7% chickpea and 7.5% Defatted Soy flour) 0% mallow powder MLP2: pasta contains legumes and 4% mallow leaves. MLP3: pasta contains legumes and 8% mallow leaves powder. MLP4: pasta legumes and 12% mallow leaves powder Each. analysis is the average of three replicates.

Table 9. Color of pasta samples

Samples	*L**	*a**	*b**
PC	70.9±0.46a	2.23±0.10a	24.95±1.15a
MLP1	66.62±0.20b	1.12±0.11b	23.61±0.36ba
MLP2	43.68±0.10c	-2.695±0.08c	22.04±0.20bc
MLP3	42.63±0.26d	-3.14±0.17d	21.79±0.20c
MLP4	41.78±0.24e	-3.37±0.12e	20.83±0.51c
P<	****	****	****

PC: pasta contains 0% Legumes and 0% mallow powder. MLP1: pasta contains legume (7% chickpea and 7.5% Defatted Soy flour) 0% mallow powder MLP2: pasta contains legume and 4% mallow leaves. MLP3: pasta contains legume and 8% mallow leaves powder. MLP4: pasta contains legume and 12% mallow leaves powder. Each analysis is the average of three replicates. SEM: Standard Error of means. (a, b, c, d and e): means within the same column differ significantly at p<0.05 when accompanied by a different superscript. * P<.05; ** P<0.01. *** P<0.001. **** P<0.0001.

The result of adding mallow powder was agreed with that of Chakraborty *et al.* (2016) who found that control pasta which is made of refined wheat flour, recorded the highest L* value, which gradually decreased with increasing amount of leaf blend incorporation. Moreover, the dark color was increased as L*, a* greenness brightness, redness and yellowness were gradually decreased as the levels of mallow leaves were increased. So, the pasta samples had dark color because of the L value < 50. This result is in agreement with those of Chakraborty *et al.* (2016) and Veena & Shivaleela (2019) who reported that the incorporation of pasta by green leafy tops rendered greenish yellow color**.** Also**,** this result is in agreement with that of Hammad and Abo-Zaid (2020) who found that supplemented noodles with 2, 4, and 6% turnip leaf powders caused a gradual decrease in color values compared to the control sample. Also, Khojah *et al.* (2017) found that the color characteristics of noodles that fortification with broccoli powder caused the same result.

Cooking quality of pasta samples

Cooking quality is an important parameter for assessing the quality of pasta for its final acceptance (Kumar, 2021).

Data in Table (10) shows that the cooking quality of pasta samples such as weight increase (%) volume increase (%) and cooking time were increased but the cooking loss was decreased as fortification with legumes flour or gradually increased as levels of mallow powder increased. This result might be due to increasing protein and fiber content that could absorb more water. Also, a low amount of solids in the cooking water indicates good cooking quality. This result may be due to increasing protein and restricted starch granules which caused a reduction in viscosity and wrapped wheat dough. The result of fortification with legume flour was in agreement with that of Bashir *et al.* (2012) and Rani *et al.* (2019) they found that fortification pasta samples with defatted soy and chickpea flour caused an increase in the protein, fibre and ash contents that caused the cooking time, water absorption, and stiffness of the pasta samples to be higher than control.

The result of fortification with mallow powder agrees with that of El-Gammal *et al.* (2016). Besides, Kumar (2021) found that the weight of cooked pasta was progressively increased by increasing the levels of *Moringa oleifera* leaf. Similarly, Veena and Shivaleela (2019) found that incorporating pasta with leafy vegetables can increase the physical, cooking quality, and acceptability of pasta products.

Sensory properties of pasta samples

Sensory evaluation of pasta is an important factor for its acceptability analysis based on sensory performance as well as for future promotion and commercialization (Kumar, 2021). During pasta cooking, the gelatinization of starch and denaturation of proteins causes the main structural changes in pasta's texture (Aravind *et al.*, 2012 and Camelo-Méndez, *et al.*, 2016).

Data in Table (11) showed that the organoleptic characteristics of pasta samples as color, flavor, taste, and texture scores of all pasta samples were acceptable. Moreover, the result of fortification pasta with legumes agrees with that of Bashir *et al.* (2012) who found that fortified pasta with 10% chickpea flour and 6% defatted soy flour resulted in better quality and nutritious pasta. On the other hand, the control had the highest characteristics compared to other pasta samples.

Table 10. Cooking quality of pasta samples

Samples	Weight increase (%)	Volume increase (%)	Cooking loss	Cooking time
PC	204±3.61D	140±1.00D	3.89±0.02A	5.3±0.06E
MLP1	216.50±1.5C	155±2.6C	3.52±0.1B	5.9±0.1D
MLP2	226.46±2.34B	175±4.36B	2.91±0.10C	6.4±0.17C
MLP3	230.42±1.04B	182±4.00B	2.67±0.12C	7.5±0.10B
MLP4	241.13±2.01A	193±2.65A	2.32±0.10D	8.7±0.17A
P<	****	****	****	****

PC: pasta contains 0% Legumes and 0% mallow powder. MLP1: pasta contains legumes (7% chickpea and 7.5% Defatted Soy flour) and 0% mallow powder MLP2: pasta contains legume and 4% mallow leaves. MLP3: pasta contains legumes and 8% mallow leaves powder. MLP4: pasta contains legume and 12% mallow leaves powder Each analysis is the average of three replicates. SEM: Standard Error of means. (a, b, c, d, and e,): means within the same column differ significantly at p<0.05 when accompanied by a different superscript. * P<0.05; ** P<0.01. *** P<0.001. **** P<0.0001.

Table 11. Sensory properties of pasta samples

Samples	Color (10)	Taste (10)	Flavor (10)	Odor	Appearance	Mouthfeel (10)	Stickiness (10)	Overall acceptability (10)
PC	9.75± 0.31a	9.03± 0.19a	9.76± 0.15a	9.4± 0.30a	9.2± 0.22a	9.20± 0.41c	9.33± 0.37c	9.21± 0.14a
MLP1	9.68± 0.29a	9.2± 0.21a	9.52± 0.32ba	9.34± 0.22a	9.4± 0.18a	9.50± 0.25ba	9.51± 0.32bc	9.34± 0.34a
MLP2	9.88± 0.18a	9.37± 0.30a	9.23± 0.22b	9.16± 0.24a	9.21± 0.24a	9.60± 0.31ba	9.75± 0.30bac	9.35± 0.13a
MLP3	8.98± 0.26b	8.62± 0.40b	8.59± 0.25c	8.79± 0.22b	8.02± 0.36b	9.70± 0.33a	9.81± 0.34ba	8.85± 0.14b
MLP4	7.98± 0.51c	7.5± 0.39c	7.43± 0.42d	8.2± 0.42c	7.67± 0.25b	9.75± 0.27a	9.89± 0.26a	8.32± 0.16c
P<	****	****	****	****	****	****	****	****

PC: pasta contains 0% Legumes and 0% mallow powder. MLP1: pasta contains legumes (7% chickpea and 7.5% Defatted Soy flour) 0% mallow powder MLP2: pasta contains legumes and 4% mallow leaves. MLP3: pasta contains legumes and 8% mallow leaves powder. MLP4: pasta contains legumes and 12% mallow leaves powder. Each analysis is the average of three replicates. SEM: Standard Error of means. (a, b, c and d): means within the same column differ significantly at p<0.05 when accompanied by a different superscript. * P<0.05; ** P<0.01. *** P<0.001. **** P<0.0001

The result of fortification with mallow powder caused a slow decrease in sensory properties, this result might be due to mallow leaves not having an especially strong or exciting taste but do make a pleasant addition, these results agree with those of Vadivel *et al.* (2016) and Fakhfakh *et al*. (2017). Nonetheless, the high level of fortification caused a decrease in sensory quality characteristics scores. This result agrees with that of Hammad and Abo-Zaid (2020).

CONCLUSION

Composite flours made from wheat, chickpea, defatted soy flour, and mallow leaves powder have demonstrated good rheological characteristics. Therefore, they are suitable for producing high-quality pasta. Additionally, increasing the amount of mallow leaves powder enhances the nutritional value, physical properties, and sensory qualities of the pasta.

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الملخص العربي

خصائص جودة المكرونة المدعمة بدقيق البقوليات ومسحوق أوراق الخبيزة ((*Malva parviflora* L.))

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هدفت هذه الدراسة إلى تصنيع مكرونة مدعمة بدقيق البقوليات (٧٪ فول الصويا منزوع الدهن و٧٪ دقيق الحمص) أو بمسحوق أوراق الخبيزة (*Malva parviflora* .L) بنسب ٠ و٤ و٨ و١٢٪. تم دراسة الخصائص الريولوجية لخليط الدقيق المركب، والتركيب الكيميائي، والقوام، واللون، والنشاط المائي للمكرونة غير المطهية، إضافة إلى جودة الطهي والخصائص الحسية لعينات المكرونة المطهية. أظهرت النتائج أن الخصائص الريولوجية لخليط الدقيق زادت من قدرة العجين على امتصاص الماء، كما زاد وقت نمو العجين ووقت الوصول، في حين انخفض معدل ثبات العجين) وضعف العجين عند إضافة دقيق البقوليات أو زيادة مستويات مسحوق أوراق الخبيزة. كذلك، أدى استخدام دقيق البقوليات أو زيادة كمية مسحوق أوراق الخبيزة إلى زيادة تدريجية في محتويات البروتين، الرماد، الدهون، الألياف، الفيتامينات، والمعادن، بينما انخفض محتوى الرطوبة والكربوهيدرات في عينات المكرونة. بالإضافة إلى ذلك، انخفضت قيم اللون (L* و a* وb*) تدريجيًا في عينات المكرونة غير المطهية مع إضافة دقيق البقوليات أو بزيادة مستويات أوراق الخبيزة. أما بالنسبة لجودة المكرونة بعد الطهي، فقد لوحظت زيادة في الوزن والحجم ووقت الطهي، في حين انخفض الفاقد أثناء الطهي تدريجيًا مع إضافة دقيق البقوليات أو زيادة مسحوق أوراق الخبيزة. وأظهرت النتائج أن جميع عينات المكرونة كانت مقبولة حسيًا، مما يشير إلى إمكانية إنتاج مكرونة ذات قيمة غذائية عالية وخصائص جودة ممتازة عند تدعيمها بدقيق الحمص وفول الصويا منزوع الدهن ومسحوق أوراق الخبيزة.

الكلمات الرئيسية: الحمص، فول الصويا، أوراق الخبيزة، المكرونة، اللون، القوام.