Mung Bean

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Introduction

Mung bean (*Vigna radiata L. Wilczek*) popularly known as green gram, believed to be native crop of India, is a tiny circular shaped bean in green color widely cultivated throughout Asia, including India, Pakistan, Bangladesh, Sri Lanka, Thailand, Laos, Cambodia, Vietnam, Indonesia, Malaysia, South China, and Republic of Formosa. This short-term legume can grow in varying environmental conditions, and later it expands it reach to the USA, Australia, and Africa. In general, mung bean is a source of high-quality protein which can be consumed as whole grains, dhal, or sprouted form and is an excellent complement to rice in respect to balanced human nutrition. In addition to being the prime source of human food and animal feed, it plays an important role in maintaining the soil fertility by enhancing the soil physical properties and fixing atmospheric nitrogen.

Structure of Mung Bean

Mung bean is an annual crop that is highly branched and is about 60–76 cm tall (Oplinger et al. 1990) with a slight tendency of twinning in upper branches. The central stem of this crop is roughly erect, but the side branches are semi-erect. The leaves of the plant are trifoliate, and it is deep-rooted. Clusters of 12–15 flowers are situated at the top of the plant, and eventually these flowers will develop into small cylindrical pods. The pods of this fully fertile and self-pollinated crop are linear,

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A. Manickavasagan, P. Thirunathan (eds.), *Pulses*,
https://doi.org/10.1007/978-3-030-41376-7_12

sometimes curve, round, and slender. The seeds enclosed within the pods are small and nearly globular. The three major components of dicotyledonous green gram seed are seed coat, cotyledon, and embryo accounting 12.1%, 85.6%, and 2.3% of the whole seed, respectively. Seed coat or testa is an outer covering which protects the embryo. The embryonic shoot above the cotyledon is epicotyl, and the embryonic root below the cotyledon is hypocotyl. Micropyle is a small pore on the seed that allows water absorption, and the hilum is a mark left on the seed coat by the stalk which attached the ovule to the ovary wall before it became a seed (Sefa-Dedeh and Stanley 1979).

Physical and Engineering Properties of Mung Bean

The knowledge of physical and engineering properties of mung bean is necessary for the designing and development of various separating, handling, storing, and drying systems, processes and controls in analysis, and determining the efficiency of the equipment required for the postharvest processing of this food legume. The relevant physical and engineering properties of green gram which include shape, size, mass, volume, bulk density, true density, porosity, angle of repose, and projected area are enlisted in Table 1. These properties are important for the quality of its deprived products such as texture of sprouts and consistency of dhal (Fig. 1).

Table 1 Physical and engineering properties of mung bean

Physical and engineering properties	Value
Length (mm)	4.9
Width (mm)	3.7
Thickness (mm)	3.6
Geometric mean diameter (mm)	4.3
Sphericity	0.82
Volume (mm^3)	33.2
Thousand seed weight (g)	35.6
Bulk density (kg/m^3)	756.81
True density (kg/m^3)	1335.4
Porosity (%)	40.8
Terminal velocity (m/s)	7.5
Angle of repose (degree)	27.6
Projected area (mm^2)	18.4

Reproduced from Dahiya et al. (2015)

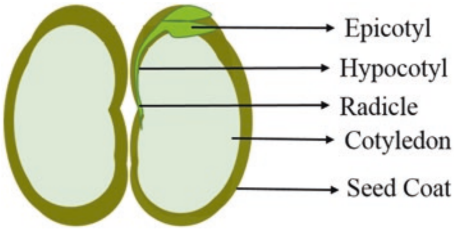

Fig. 1 Structure of mung bean

Nutritional Composition

Green gram can be a rich source of protein with higher digestibility and can serve to convalescing babies or malnutrition people. The nutrients are not distributed uniformly in major components such as seed coat, cotyledon, and embryo of the mung bean seed. The protein and lipids are found to be high in embryo, whereas the starch and crude fiber are concentrated in cotyledons and seed coats, respectively. The average moisture content present in the whole mung bean seed is 10.6 g/100 g of whole green gram with high protein (22.9 g), fat (1.2 g), total carbohydrate (61.8 g), crude fiber (4.4 g), and ash (3.5 g) per 100 g of sample (Adsule et al. 1986). The presence of antinutritional factors such as tannins (366.6 mg/100 mg), phytic acid (441.5 mg/100 g), hemagglutinin, trypsin inhibitors, proteinase inhibitors, and polyphenols (462.5 mg/100 g) were reported in mung bean, which affect the digestion and bioavailability of full nutrition (Mubarak 2005). The average chemical composition of the whole green gram is tabulated in Table 2.

Production Status

Pulses are one of the important groups of crops that plays a vital role in addressing the nutritional security all around the world. Pulses are cultivating throughout the world, and almost half of its production occurs in Asia especially in India. India is the largest producer of pulses and cultivated over 29 million hectares of area and recorded the highest ever production of 25.23 Mt during 2017–2018. In the case of mung bean, more than 3 Mt of green gram are produced in the world annually (FAOSTAT 2016). India contributes to the major share of mung bean in the world market with a production of 1.9 Mt in which Rajasthan with 42% area and 39% production outshined in the total mung bean production in the country (Ministry of Agriculture and Farmers Welfare, India 2018) which is followed by China (0.98 Mt), Myanmar (0.400 Mt), Indonesia (0.300 Mt), Thailand (0.210 Mt) and Pakistan (0.199 Mt). China is the largest exporter (Misiak et al. 2017), and India is the largest importer of mung beans.

Table 2 Chemical composition of the whole green gram seed

Carbohydrate (%)		Amino acid (g/16 g of nitrogen)		Lipid (% of total fat content)		Vitamin (mg/100 g dw)		Minerals (mg/100 g dw)	
Glucose	0.3	Alanine	4.1	Total saturated fatty acids	27.7	Thiamine	0.5	Calcium	113.4
Total soluble sugar	5.6	Arginine	5.8	Total unsaturated fatty acids	72.8	Riboflavin	0.3	Copper	1.0
Reducing sugar	1.8	Aspartic acid	13.0	Palmitic acids	14.1	Niacin	2.2	Iron	5.9
Nonreducing sugar	6.3	Cysteic acid	13.5	Stearic acid	4.3	Vitamin C	3.1	Potassium	956.6
Sucrose	1.3	Glutamic acid	18.3	Oleic acid	20.8	Pantothenic acid	1.9	Magnesium	162.4
Raffinose	1.1	Glycine	3.6	Linoleic acid	16.3	Nicotinic acid	1.6	Manganese	1.05
Stachyose	1.6	Histidine	3.2	Linolenic acid	35.7	–	–	Phosphorous	384.4
Verbascose	2.7	Isoleucine	4.3	Behenic acid	9.3	–	–	Sodium	16.7
Total dietary fiber	18.8	Leucine	7.6	–	–	–	–	Phytin phosphorus	171.3
Lignin	3.9	Lysine	6.5	–	–	–	–	Zinc	2.7
Cellulose	3.9	Methionine	1.2	–	–	–	–	–	–
Hemicellulose	4.7	Phenylalanine	5.4	–	–	–	–	–	–
Amylose	24	Proline	4.5	–	–	–	–	–	–
Starch	47	Serine	4.9	–	–	–	–	–	–
–	–	Threonine	3.2	–	–	–	–	–	–
–	–	Tryptophan	1.2	–	–	–	–	–	–
–	–	Tyrosine	2.7	–	–	–	–	–	–
–	–	Valine	5.1	–	–	–	–	–	–

Reproduced from Dahiya et al. (2015)

Postharvest Processing

Harvesting of the mung bean is usually done within 75–90 days when the pods turn dark or half to one third mature. The maturity of the pod is not uniform because of the extended period of flowering. Mature pods are usually handpicked. The moisture content present in the pods at the time of harvest is 13–15%, and to enhance the storage life, the moisture content should bring down to 12% by drying. In some newer varieties, pod matured uniformly, and the whole plant will be harvested and sun dried before threshing, and later seeds are separated from the pods by beating or trampling. Processing step brings the mung bean nearer to human consumption. Modernization of agriculture leads to farm mechanization which imparts combined harvesting and threshing equipment at farm level. Several farm machineries are available now for the harvesting of pulses which reduces the work load and time consumption.

Processing

Processing of mung bean is important in improving its nutritional value. It is concerned with its value addition. Milling of mung bean is one of the important processing methods employed to converting into dhal by decutilating and splitting. The process milling implies the removal of outer husk of mung bean and splitting the bean into two halves. Cleaning, grading, conditioning, dehusking, and polishing are the important unit operations in the mung bean milling process. The overall process flow is demonstrated in the given flowchart (Fig. 2) (Sahay and Singh 2004). Both wet milling and dry milling are preferred for commercial-scale production.

Unit Operations Involved in Green Gram Milling

Cleaning

Prior to the milling process, the mung beans received in milling plants should undergo a cleaning process in which the mung beans are cleaned from different organic and inorganic impurities such as chaffs, dust, stones, etc. with the help of screens, air drafts, or de-stoners. The cleaned grams are then graded according to their size in order to maintain the quality of the final product mostly by reel grader.

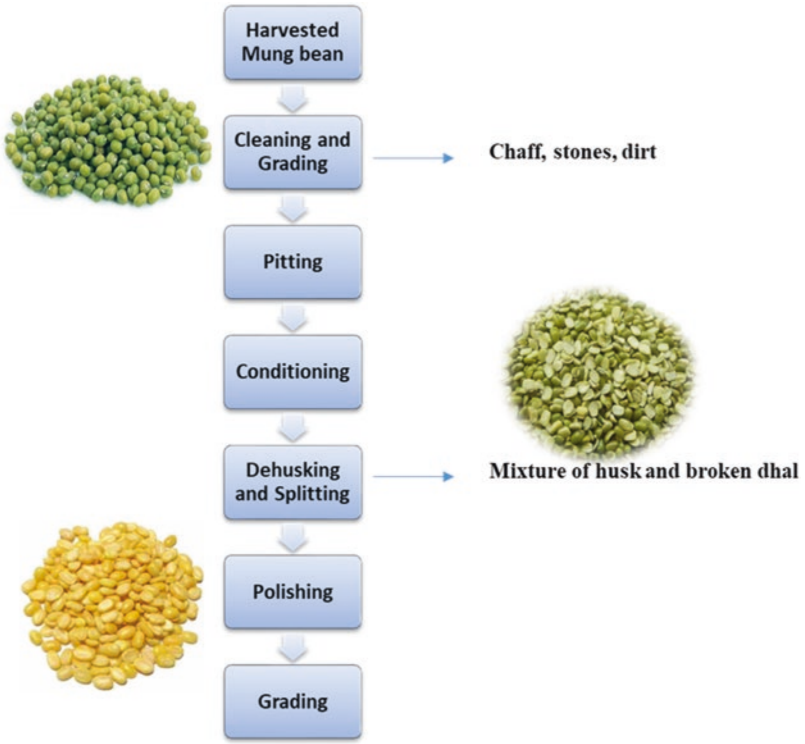

Fig. 2 Postharvest unit operation involved in mung bean processing

Conditioning

A gum/mucilaginous layer is present between the cotyledon and the outer kernel of the green gram. This gum adheres to the cotyledon to the seed coat. The thickness of the gum governs the degree of adherence, and it also influences the severity of conditioning. The main purpose of conditioning is to loosen the outer seed coat from cotyledon and make possible kernel separation. There are different ways of conditioning including water treatment, hydrothermal treatments, etc. with an alternate wetting and drying to reduce the milling losses. The drying time varies depending upon the type of milling method used for green gram processing.

Milling

Milling of mung bean involves the removal of outer husk and splitting the beans into two halves. Dehusking and splitting are important and major unit operations of mung bean milling. The conditioned mung beans are subjected to abrasive forces for the removal of outer husk. The dehusking is usually done with emery rolls, which furtherly splits in to two halves (dhal) by using vertical disc burr mill. Later the husk is aspirated off, and the split beans are separated by sieving. Since the kernel is tightly attached to the outer covering, alternate wetting and drying are followed for facilitating the removal of husk. Generally, there are two types of milling, namely, wet milling and dry milling. Both types of milling involves two basic steps: (1) preconditioning of mung bean for loosening the husk and (2) further milling of mung bean.

Wet Milling

Wet milling involves cleaning of mung bean followed by soaking in water for 4–12 h. After draining the water, soaked mung beans are mixed with red earth (2–3%) and heaped for overnight for effective moisture diffusion and equilibrium. Alternate sun drying (thin layers) and tempering of mung beans for 2–4 days have to be done prior to milling. Red earth should be separated from mung beans before milling. The milled beans can be graded according to the specifications. Unhusked beans can again pass for milling.

Dry Milling

In case of dry milling, pitting or scratching of outer surface will be done after the cleaning of mung beans followed by oil pretreatment and sun drying. The scratches are usually made by emery roller, and the oil (1.5–2.5 kg/t of green gram) mixed with mung beans is held for 12 h in a mixing vessel. Later oiled grains are spread for sun drying. After 3–4 days of drying, 3–5% water is sprayed on dried mung beans which are then subjected to milling. Whole dehusked beans recovered from the first milling shall undergo sun drying again after addition of water, followed by dehusking and splitting to obtain Grade (I) split dhal. In bigger dhal mills, dryers are used instead of sun drying.

Polishing

Polishing of dehusked and split beans is usually done to create a desirable shine for better consumer acceptability by treating it with small quantity of oil and water. Dhal is polished in different ways, such as nylon polish, oil/water polish, leather and makhmal polish. Generally polishing is done using soap stone, oil or water. The presence of oil and water improves the shine of the final product. The polished beans are graded according to the size to maintain the quality of final product.

Table 3 US grade and grade requirement for the class of mung bean

Maximum limits of							
		Foreign matters					
Grade	Moisture	Total (including stones)	Stones	Clean-cut weevil bored	Total damaged grains	Contrasting classes	Classes that blend
US No. 1	18.0	0.5	0.2	0.1	2.0	0.5	5.0
US No. 2	18.0	1.0	0.4	0.2	4.0	1.0	10.0
US No. 3	18.0	1.5	0.6	0.5	6.0	2.0	15.0

Reproduced from https://www.gipsa.usda.gov/fgis/standards/Bean-Standards.pdf (2017)

Table 4 AGMARK Grade specification for green gram (whole)

Maximum limits of tolerance (percent by weight)						
		Foreign matters				
Grade	Moisture	Organic	Inorganic	Other edible grains	Damaged grains	Weevilled grains percent by count
Special	10.0	0.10	Nil	0.1	0.5	2.0
Standard	12.0	0.50	0.10	0.5	2.0	4.0
General	14.0	0.75	0.25	3.0	5.0	6.0

Reproduced from https://dmi.gov.in (2005)

Grading

The cleaned grams are graded according to their size in order to maintain the quality of the final product mostly by reel grader. The polished beans are graded according to the size to maintain the quality of final product. Grading offers numerous advantages such as the following: it reduces the cost of marketing and transportation, assures the quality of produce, and farmers can get better price for their produce. US-based classification includes Grade I, Grade II, and Grade III. In this total defect percentage is different for each grade with same moisture content (Table 3). Directorate of Marketing Inspection (India) has drawn up specification of green gram for various quality factors under the Agricultural Produce (Grading and Marking), Act, 1937. The grade standards specified for green gram whole (Table 4), split-husked (Table 5) and split-unhusked (Table 6), are given below.

Product Development

Pulses are good sources of nutrients, vitamins, minerals, and other functional bioactive ingredients. Due to these factors, pulses are used as an important constituent of product in the development of different food formulations. The characteristic nature

Table 5 AGMARK Grade specification for green gram split (husked)

Maximum limits of tolerance (percent by weight)							
		Foreign matters					
Grade	Moisture	Organic	Inorganic	Other edible grains	Damaged grains	Weevilled grains percent by count	Brokens
Special	10.0	0.10	Nil	0.1	0.5	1.0	1.0
Standard	12.0	0.50	0.10	0.5	2.0	2.0	3.0
General	14.0	0.75	0.25	3.0	5.0	3.0	6.0

Reproduced from https://dmi.gov.in (2005)

Table 6 AGMARK Grade specification for green gram split (unhusked)

Maximum limits of tolerance (percent by weight)							
		Foreign matters					
Grade	Moisture	Organic	Inorganic	Other edible grains	Damaged grains	Weevilled grains percent by count	Brokens and fragments
Special	10.0	0.10	Nil	0.1	0.5	1.0	0.5
Standard	12.0	0.50	0.10	0.5	2.0	2.0	2.0
General	14.0	0.75	0.25	3.0	5.0	3.0	5.0

Reproduced from https://dmi.gov.in (2005)

of pulses is useful for the development of products like rich in protein, fiber, antioxidant, gluten-free, and low in fat and glycemic index (GI). The functional properties such as water holding capacity, oil holding capacity, and emulsification activity of pulse flours considerably contribute to the better quality of the product (Mazumdar et al. 2016).

A wide range of value-added products from green gram is available in the market as well as in household level. Most commonly green gram is widely consumed in the form of whole grain, split or whole dehusked dhal, and soaked, sprouted, and germinated grains. On the other hand, salted split dhal, flaked, chips and extruded green gram product is consumed as a snack; soaked, germinated and sprout is consumed as a green salad. The flour prepared by milling of whole grain, germination, or fermentation followed by drying is used in the development of functional foods for children, lactating mother, and infants, special formulated diet for patients, as well as ready-to-eat products. Generally, various bakery and confectionary products are produced by using refined or whole wheat flour as a base ingredient. In this context, replacement of wheat flour with alternative ingredient received considerable attention from the last three decades in food product development activities. Various literature is available for use of green gram or mung bean flour for the formulation of various value-added products like bread, cookies, biscuits, *dosa*, *idli*, functional beverages, and other ethnic foods (Fig. 3). Increase in nutritional awareness among the consumer and demand for health beneficial value-added products have been

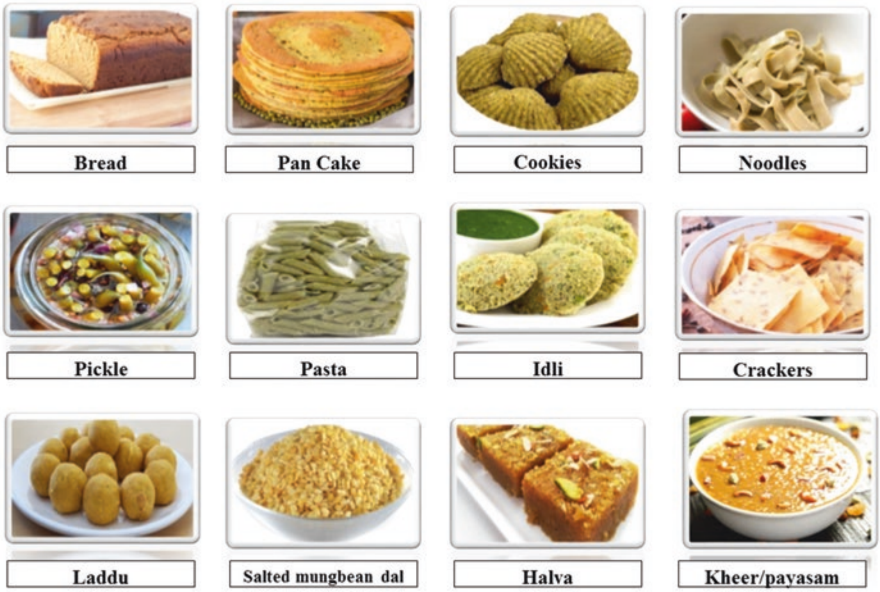

Fig. 3 Processed products of mung bean

increased nowadays to fulfill the nutritional requirement. The incorporation of green gram in various forms could improve the nutritional status of the consumer by supplying adequate nutrients, thereby helping to alleviate the nutritional-related health issues.

Biscuit, Cookies, and Crackers

Biscuit and cookies belong to the category of baked products. Generally, wheat flour, sugar, and fat are used as the main ingredients. These are convenience foods consumed throughout the world in many forms such as cookies; short dough biscuit; hard sweet, snack crackers; soda crackers; and sweet biscuit. Cookies are prepared by the inclusion of a wide variety of dried nuts, chocolate chip, raisins, and dehydrated fruits. Biscuit and cookies have a longer shelf life because of lower water activity. They are nutritious and available in different functional forms (Davidson 2019). Shukla et al. (2016) developed the protein-enriched biscuit fortified with green gram flour. The experiment is carried out to replace the wheat flour with green gram flour (30%, 40%, 50% and 60%). It was observed that by incorporating green gram flour, the diameter and spread ratio were decreased with increase in addition of flour. The thickness and nutritional composition like protein, fat, and ash content were increased. The study revealed that incorporation of green gram flour with the replacement of wheat flour with a 30–60% level is acceptable. It not only improves the nutritional characteristics of the product but also improves the sensory quality.

Effect of incorporation of green gram flour on rheology, microstructure, and quality of cookies was investigated by Rajiv et al. (2012). The cookies were prepared by replacing wheat flour with green gram flour (10%, 20%, 30%, 40%, and 50%) in order to improve the proximate composition of the cookies. By increasing incorporation of green gram flour level extensibility, elasticity and peak viscosity of dough are decreased. The spread ratio of developed cookies ranged from 8.80 to 7.40. Cookies prepared by incorporating 40% of green gram flour and 60% of sodium stearoyl-2-lactylate as emulsifier were acceptable. Developed cookies were rich in protein, iron, calcium, and zinc, and total dietary fiber 1.25, 1.6, 2.0 and 2.3 times respectively than the control sample. Similarly, the addition of green gram flour of more than 50% yields hard texture and qualitatively unacceptable cookies. Tulse et al. (2014) studied the rheological and quality characteristics of cookies. The cookies were prepared by incorporation of co-milled wheat (70, 80, 90)/green gram (5, 10, 15)/barley gram (5, 10, 15). Water holding capacity and breaking strength increased; on the other hand hardness, spread ratio, extensibility, and stability of dough decreased by an increase in the proportion of green gram and barley flour. The cookies developed in the ratio 70:15:15 of co-milled wheat/green gram/barley were unacceptable and produce hard texture. The blend of co-milled wheat/green gram/barley at 80:10:10 cookies were good in textual quality and mouthfeel and rich in protein (12.30%) and dietary fiber (8%).

Savory crackers were developed by replacing the wheat flour partially or completely with green gram flour, and physicochemical and sensory attributes were investigated by Venkatachalam and Nagarajan (2017). Crackers were prepared at a ratio of wheat flour to green gram flour (100:0; 80:20; 60:40; 40:60; 20:80; 0:100) with additional ingredients like sugar, salt, sodium bicarbonate, vegetable oil, and water. All ingredients are mixed thoroughly and made as a dough. Afterward dough was sheeted and cut into small squares. Thereafter crackers were baked at 180 °C for 11 min in a conventional rotary oven. Products were removed and flavor, honey, and garlic were brushed on the surface of the crackers. The baking process was continued for another 4 min at the same temperature. It was pointed out that the addition of green gram flour improves the nutritional characteristics and functional properties of the crackers. The considerable changes in color value ($L*$, $a*$, $b*$, $\Delta E*$), ultrastructure, antioxidant activity, and sensory attributes were noticed in all formulations.

By the literature, it can be concluded that green gram flour is an excellent alternative against wheat flour up to an acceptable level. It not only improves the product sensory quality but also enriches the nutritional composition. Thereby it improves the nutritional status of the consumers.

Extruded Products

Extrusion is a high-temperature short-time process where a set of blended moist ingredients is enforced through a small opening in a die with a design specific to the food. Hot extrusion would be carried out by heating the product above 100 °C and in cold extrusion at ambient condition. It produces high-quality texturized products by modifying flour functionality and improves the digestibility and sensory characteristics (Patil and Kaur 2018). The extrusion study was carried out by blending green gram and rice flour by Chakraborty and Banerjee (2009). The expansion ratio of extruded product is decreased by an increase in moisture content; it shows that temperature and moisture content has a significant effect on product expansion ratio. The dough viscosity is decreased by an increase in the speed of screw which results in low-power consumption. Morphological characteristics showed gelatinization of starch and denaturation of protein by forming elongated and parallel air cells in extruded products. Bhattacharya (1996) investigated the effect of incorporation of green gram flour on extrudate characteristics. The operating conditions for double-screw extruder were as follows: screw speed (100–140 rpm); barrel temperature (100–175 °C); and barrel diameter (31 mm). The green gram to rice flour ratio was 1:1, and moisture content of the blended mixture was 18%. The expansion ratio and density of the extrudate varies between 1.31 and 2.53 and 149–1089 kg/m^3, respectively. At higher temperature level, torque was highest. Shear stress highly depended on process variables; on the other hand, temperature and speed of barrel directly influenced the quality characteristics of extrudates. Lower screw speed and higher barrel temperature yielded better quality of expanded products.

Protein-rich pasta was prepared by incorporation of green gram semolina to durum semolina in the ratio of 500:0, 400:100, 300:200, 200:300, and 100:400. The flour was mixed with water and formed a dough. The dough was extruded using a cold extruder and finally dried at 75 °C for 3 h. The viscosity of dough was decreased with an increase in the proportion of green gram semolina. Change in firmness, color, protein, and ash content of pasta was noticed. Pasta prepared by addition of 80% green gram semolina is unacceptable and sticky in nature, and higher cooking loss was observed. Incorporation of green gram semolina at the level of 60% yield better quality of pasta with respect to taste, texture, and quality. It can be concluded that green gram semolina offered a better quality of product as well as improved the nutritional composition (Jyotsna et al. 2013).

There is an increase in demand for ready-to-eat, ready-to-cook, and ready-to-serve convenience food from the last two decades. Pardeshi et al. (2013) developed ready-to-cook green gram nuggets by using cold extruder. The formulations were made by inclusion of wheat flour at the level of 0–30% in green gram flour. Steaming of the extrudate was done at 1.0 kg/cm^2 pressure followed by final drying (60 °C) up to desirable moisture level (7.73%). The optimized parameters of wheat flour (24%), steaming time (6 min), and initial moisture content (36.50%) yielded better quality of mung bean nuggets. The proximate composition of green gram nuggets was as follows: 65% carbohydrates; 22.50% protein; 1.5% fat, 3.5% ash, and 7.73% (wb) moisture. Ready-to-cook green gram nuggets could be stored up to 114 days at 30 °C in metalized polyester bags.

Bread

Bread and cake are staple foods prepared by using wheat flour, sugar, yeast, and shortening. Wheat flour containing 11.5–12.50% protein for bread and less than 10% for cake making is well suitable. Bread is made by mixing all ingredients in the form of dough, which has been baked at 225 °C in the oven. The protein content in the green gram ranges from 20% to 25% (Ganesan and Xu 2018). Thompson et al. (1976) investigated the preparation and application of mung bean flour in bread making. Initially dehulling of mung bean was carried out by steam conditioning at 7 psi for 5–7 s. After a 1-day resting period, dehulling was performed in pressure plate huller. Dehulled beans were milled into fine flour by using Buhler experimental mill. Proximate, functional, and rheological characteristics of mung bean flour were analyzed before the preparation of bread. It was noticed that 87% dehulling performance was achieved. The protein, fiber and ash content of mung bean range from 21.6–23.2%, 0.15–0.19% and 3.28–3.68% respectively. The bread was prepared by the straight dough method by adding mung bean flour (0–20%). After baking considerable changes in physical and sensory attributes were noticed. Inclusion of 20% mung bean flour in bread making produces lower loaf volume and a dark color compared to the control sample. The study points out that the replacement of 15% mung bean flour with wheat flour considerably produces the good quality of bread and the product approximately ten times rich in protein.

Noodles

Noodles are the convenience food prepared by either soft or hard wheat and consumed worldwide (Gulia et al. 2014). Protein-rich instant noodle was prepared, and its quality was analyzed by Jayarathne et al. (2006). High-protein noodles were prepared by using the optimal formulation: wheat flour (75 kg), soybean (10 kg), green gram (10 kg), and egg flour (5 kg). The flours were mixed with water, sodium bicarbonate, salt, sugar, and sodium tripolyphosphate. The dough was spread into a sheet and cut into noodles by sharp knife. Steaming and cooking are performed in a closed chamber at 100 °C for 90 s. The noodles were removed and allowed to cool at ambient condition. Frying was carried out for 90 s at 155–165 °C. The fried noodles were cooled and hermetically packed in oriented polypropylene pouches. The product was safe up to 6 months of the storage period; peroxide value (5.5) and moisture content (2.8%) of the products were within the acceptable standards. The nutritional composition of noodles was as follows: moisture 2.8%, ash 2.4%, crude protein 15%, fat 1.8%, and free fatty acids 0.6%.

Pickle

Pickling is a process of preservation of fruits and vegetables through controlled fermentation under acidic condition (pH < 4.5) by the addition of salt or brine, vinegar or acetic acid, sugar, oil, spices, and condiments (Erten et al. 2015). Protein-rich germinated green gram pickle was developed, and the preservation studies were carried out by Puranik et al. (2011). The germinated green gram pickle was prepared by the addition of salt, vinegar, garlic, oil, and other spices and condiments. The optimum level of ingredients for 50 g of pickle was oil 16 mL, vinegar 6 mL, garlic 7 g, and salt 4 g. The texture, flavor, and color of the product were observed within the acceptable limit with high protein and fiber content in its proximate composition. The product has a shelf life up to 2 months of storage period at the ambient condition with little or no change in its quality characteristics.

Future Trends in Processing and Product Development

Pulses are an integral part of our daily diet, rich in protein and fiber, and, hence, serve as an important source of the nutrient. Generally, green grams are harvested once the desirable maturity stage is attained. Adoption of improved harvesting, handling, drying, and storage methods is essential in order to obtain higher quality of processed food products. Apart from conventional sun drying, novel drying methods like microwave drying, radio-frequency drying, infrared drying, and other hybrid drying methods gain special attention in disinfection and drying of grain. Processing of green gram or pulses is the biggest challenge to obtaining the maximum dhal (split) yield. Prior to milling, pretreatment of green gram needs special attention to maximize the milling yield. Pretreatments like wet, hydrothermal, chemical, and enzymatic treatments are in practice. Currently, by using traditional, improved, or novel milling techniques, up to 75–80% of dhal yield was achieved. Still, research and innovation are essential to improve the milling yield, development of improved milling equipment, and drying technologies with low product loss and minimize the milling co-products.

Change in living lifestyle and demand for nutritious, convenience, and functional foods are increased. In the market convenience products like ready-to-eat, ready-to-cook, and ready-to-serve categories gain special interest toward the consumers. The value-added mung bean products like cookies, bread, biscuit, noodles, pasta, vermicelli, chips, salted split dhal, green gram flake, texturized products, and enriched flour mix are available in the market. In addition, incorporation of green gram flours produced by germination, sprouting, soaking, and fermentation serves as a perfect alternative toward wheat flour in the preparation of various bakery and confectionary products. Because of its high protein and fiber and low glycemic index, green gram flour is well suitable for therapeutic and novel food formulations. Development of improved processing methods, digestion and absorption studies, fortification, enrichment, level of antinutritional factor reduction, microbial safety, improved packaging, and storage methods with no or little effect on nutritional composition and product quality need further investigations.

Conclusion

Green gram is a leguminous crop that stores atmospheric nitrogen in root nodules, thereby considerably reducing the usage of chemical fertilizers in farm applications. It serves as an important source of protein, fiber and mineral in vegetarian diet. The wide range of milling technologies are available to separate the inner endosperm from outer husk. The efficiency and milling yield vary with the type of method used and preprocessing treatments. Postharvest processing and value addition are the major segments in effective utilization of mung bean. Processed products enriched and fortified with the addition of mung bean flour is very popular in the market. There is a growing demand for ready-to-eat, ready-to-cook, and ready-to-serve functional food due to awareness in consumers. Incorporation of green gram flour with wheat flours offers better quality of bakery products. Inclusion of sprouted, germinated, roasted flours in product development improves the product quality, nutritional composition, and sensory characteristics. The consumption of green gram and its value-added products improve the nutritional status of individuals; hence it serves an important source of nutrients and helps to eradicate the malnutrition in the world.

References

Adsule, R. N., Kadam, S. S., Salunkhe, D. K., et al. (1986). Chemistry and technology of green gram (*Vigna radiata* [L]. Wilczek). *Critical Reviews in Food Science and Nutrition, 25*(1), 73–105.

Bhattacharya, S. (1996). Twin-screw extrusion of rice-green gram blend: Extrusion and extrudate characteristics. *Journal of Food Engineering, 32*, 83–99.

Chakraborty, P., & Banerjee, S. (2009). Optimisation of extrusion process for production of expanded product from green gram and rice by response surface methodology. *Journal of Scientific and Industrial Research, 68*, 140–148.

Dahiya, P. K., Linnemann, A. R., Van Boekel, M. A. J. S., et al. (2015). Mung bean: Technological and nutritional potential. *Critical Reviews in Food Science and Nutrition, 55*(5), 670–688.

Davidson, I. (2019). *Biscuit, cookie and cracker production-process, production and packaging equipment*. Boca Raton, FL: CRC Press.

Department of Marketing Inspection. (2005). Retrieved May 28, 2019, from https://dmi.gov.in.

Erten, H., Boyaci-Gündüz, C. P., Ağırman, B., et al. (2015). Fermentation, pickling, and Turkish table olives. In Y. H. Hui, E. O. Evranuz, H. Erten, G. Bingöl, & M. E. J. Flores (Eds.), *Handbook of vegetable preservation and processing* (2nd ed., pp. 209–230). Boca Raton, FL: CRC press.

FAOSTAT (2016). Retrieved May 28, 2019 from https://www.fao.org/3/a-br622e.pdf.

Ganesan, K., & Xu, B. (2018). A critical review on phytochemical profile and health promoting effects of mung bean (*Vigna radiata*). *Food Science and Human Wellness, 7*, 11. https://doi.org/10.1016/j.fshw.2017.11.002.

Gulia, N., Dhaka, V., & Khatkar, B. S. (2014). Instant noodles: Processing, quality, and nutritional aspects. *Critical Reviews in Food Science and Nutrition, 54*(10), 1386–1399.

Jayarathne, U. S., Arampath, P. C., & Pemasiri, P. F. S. (2006). Development and quality evaluation of a protein-enriched instant noodle. *Tropical Agricultural Research, 18*, 1–11.

Jyotsna, R., Milind, Sakhare, S. D., et al. (2013). Effect of green gram semolina (Phaseolus aureus) on the rheology, nutrition, microstructure and quality characteristics of high-protein pasta. *Journal of Food Processing & Preservation, 38*, 1965–1972.

Mazumdar, D., Saikat, D., et al. (2016). Chapter 5. Utilization of pulses – Value addition and product development. In *pulses for sustainable food and nutrition security in SAARC region* (pp. 65–97). Bangladesh: SAARC Agriculture Centre.

Ministry of Agriculture and Farmers Welfare (2018). Pulses revolution from food to nutritional security-success report. Retrieved May 23, 2019 from https://www.farmer.gov.in/SucessReport2018-19.pdf.

Misiak, K., Gorna, B., Krol, E., et al. (2017). Yield and quality of mung bean (*Vigna radiata* (L) Wilczek) seeds produced in Poland. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture, 74*(2), 149.

Mubarak, A. E. (2005). Nutritional composition and antinutritional factors of mung bean seeds (Phaseolus aureus) as affected by some home traditional processes. *Food Chemistry, 89*(4), 489–495.

Oplinger, E. S., Hardman, L. L., Kaminski, A. R., et al. (1990). Mungbean. In *Alternative feed crop manual*. Madison, WI: University of Wisconsin.

Pardeshi, I. L., Bhuskade, S. A., & Kalmegh, V. B. (2013). Development of cold extruded ready-to-cook Mung (Vigna radiata L.) nuggets. *Journal of Food Research and Technology, 1*(1), 21–28.

Patil, S. S., & Kaur, C. (2018). Review current trends in extrusion: Development of functional foods and novel ingredients. *Food Science and Technology Research, 24*(1), 23–34.

Puranik, V., Mishra, V., Singh, N., et al. (2011). Studies on development of protein-rich germinated green gram pickle and its preservation by using class one preservatives. *American Journal of Food Technology, 6*, 742–752.

Rajiv, J., Lobo, S., Jyothilaxmi, A., et al. (2012). Influence of green gram flour (Phaseolus aureus) on the rheology, microstructure and quality of cookies. *Journal of Texture Studies, 43*, 350. https://doi.org/10.1111/j.1745-4603.2012.00346.x.

Sahay, K. M., & Singh, K. K. (2004). *Unit operations of agricultural processing*. New Delhi: Vikas Publishing House Pvt. Ltd.

Sefa-Dedeh, S., & Stanley, D. W. (1979). The relationship of microstructure of cowpeas to water absorption and dehulling properties. *Cereal Chemistry, 56*(4), 379–386.

Shukla, R. N., Mishra, A. A., & Gautam, A. K. (2016). Development of protein enriched biscuit fortified with green gram flour. *Food Science Research Journal, 7*(1), 112–118.

Thompson, L. U., Hung, L., Wang, N., Rasper, V. F., & Gade, H. (1976). Preparation of mung bean flour and its application in bread making. *Canadian Institute of Food Science and Technology Journal, 9*(1), 1–5.

Tulse, S. B., Reshma, V., Rajiv, J., et al. (2014). Effect of co-milled wheat, green gram and barley on the rheological and quality characteristics of cookies. *Food Science and Technology International, 21*(7), 492–502.

United States Standards for Beans. (2017). Retrieved May 28, 2019, from https://www.gipsa.usda.gov/fgis/standards/Bean-Standards.pdf.

Venkatachalam, K., & Nagarajan, M. (2017). Physicochemical and sensory properties of savory crackers incorporating green gram flour to partially or wholly replace wheat flour. *Italian Journal of Food Science, 29*, 599–612.