Emirates Journal of Food and Agriculture. 2021. 33(11): 965-971
doi: 10.9755/ejfa.2021.v33.i11.2786
http://www.ejfa.me/

RESEARCH ARTICLE

Microwave-assisted pre-milling treatments of chickpea (*Cicer Arietinum*) for higher recovery

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ABSTRACT

This research was undertaken to examine the result of microwave pre-treatment on chickpea dehulling. The experiments were conducted at three microwave power levels (PL), 50, 70, and 90, at different five exposers from 1 to 3 minutes at the time interval of 30 seconds to evaluate chickpea dehulling with the pre-milling treatment of microwave exposure for achieving maximum dehulling yield, dhal yield, good dehulled grains in terms of quality with minimum dehulling loss. It was noted that dehulling yield improved with microwave power and exposure period. The highest dehulling yield, 71.02%, was achieved 90 PL with 2.5 minutes exposure and found maximum dhal yields, i.e., 66.40%, and minimum dehulling loss, 10.25%. So, this requirement was correct and better to get a higher dhal yield. These findings are also valuable for the pulse processing industry and fabricators for designing a continuous type pulse pre-milling treater unit. Hence, it could be highlighted that the microwave pre-milling treatment is more suitable for pulse processing like chickpea. This also presents an improvised method for pre-milling treatments for commercial adoption.

Keywords: Chickpea; Dehulling losses; Dhal yield; Dehulling yield; Microwave; Power level

INTRODUCTION

'Pulses' are legume seeds such as lentils, beans, peas, and chickpeas that are edible. Each of these pulse crops is available in various hues and sizes. Pulse crops are cultivated to feed the world's varied nations, and they have significant cultural and historical significance. Legume proteins are high in lysine and supplement the lysine-rich proteins not found in grains and oilseeds. Additionally, since pulses are a good source of nutrients, they help lower the risk of cardiovascular disease, diabetes, and some forms of cancer (Pastor-Cavada et al., 2011). India is the principal producer and consumer of pulses globally, accounting for 33 percent of the world area and 22 percent of the world's production of pulses. Chickpea, pigeon pea, green gram, black gram, lentil, and field pea are significant pulses crops contributing 39%, 21%, 11%, 10%, 7%, and 5% to the total production of pulses in the nation. In 2009-10, total output was 14.56 million tonnes in a 23.63 million hectare area, with an average yield of 625 kg/ha.

Moreover, India is also the largest pulses trader, showing the pulses' consumption rate in India. Chickpeas are the second most crucial crop globally, and India contributes about 65% of the total world production, being the largest chickpea producer globally. As chickpea is the utmost chief crop and most consumed crop, it is grown in at least 33 counties throughout the world, and most of these are located in South and West Asia, North and East Africa, Southern Europe, North and South America, and Australia (Singh, 1997).

The protein quality of chickpeas is better than the other pulses. In India, splited chickpea is commonly known as Chana dhal, which contains 20.8% protein, 5.6% fat, 2.7% mineral, 1.2% fiber, and 59.8% carbohydrate (Gopalan et al., 1995).

Chickpea is grouped into two types, i.e., the First one is Kabuli (the Mediterranean and middle eastern origin), and the second one is desi type (Indian origin). The Kabuli one is large seeded verities has rounded seed and the cream-colored seed coat, whereas desi type is a slight wrinkle with a dark color and having corticated seed coat (Chawan et al., 1987, Miao et al., 2009).

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Received: 13 September 2021; **Accepted:** 30 October 2021

The Indian people consumed about 80% percent of pulses in dhal and powder, the residual 20% as the complete seed and in supplementary forms like dishes (Chakjo et al., 2001) to consume chickpea, which is commonly known as Chana dhal. It undertakes many processing processes like dehulling, splitting, crushing, puffing, and toasting before milling and making it helpful for a variety of food. So, we ultimately improve physical characteristics such as appearance, texture, and culinary properties and reduce cooking time through chickpea processing. According to research, it has been found that the dehulled pulses are easy to digest by the human body (Kurien, 1987). That is why splitting and decortications of pulses become a more critical process in agro-based industries. Moreover, this is the reason for the diversity of machinery, and new methods started in the agro-industries to achieve high and good milling efficiency of pulses (Sokhansaj and Patil, 2003).

The milling efficiency of chickpea is the removal of an efficient hull without breakage and loss of cotyledon. The physical and chemical properties of chickpeas, such as size, grade, moisture content, hardness of grain content, amount of hull, and chemical nature and bond, exist between the two cotyledons affect the dehulling of chickpea (Chavan et al., 1987). Erskine and George (2014) have shown that for an abrasive device, dehulling efficiency can be obtained efficiently by optimizing sample size, rotating speed, diameter, clearance, grit size, and retaining abrasive time.

The outer seed coat of grain is rigid and imparts an unpleasant taste because of the nutrient in the seed coat. It also reduces the nutrient quality of pulses to improve its nutrient properties by removing hull is carried out by a method of dehulling, which helps to improve physical appearance and reduce the cooking time of chickpeas (Tiwari et al., 2007). The dehulling of chickpea is done by two methods, i.e., Wet method and Dry method (Kurien, 1997). These methods loosen the bond between hull and cotyledon for dehulling. The wet method involved the soaking of grain in water for 6 to 8 hours and then exposure to sun drying for 3 to 4 days to attain dehulling at moisture content for better milling efficiency. Whereas in the dry method, to improve soaking time, the grain is pitted. These scratched grains are combined with 1% edible oil and then sun-dried for two to three days; at the end of the drying process, 2.5 percent water is sprayed and mixed in, followed by overnight tempering with heaped grain. Moreover, grain is ready to be dehulled. Nowadays, the wet method is rarely used.

In order to reduce the pre-treatment time, several kinds of research have been carried out on heat treatment for pulses dehulling as sudden heat increases the loosening of hulls from cotyledon in pulses. As a result, it may be beneficial to perform heat treatments to loosen the hulls. Thermal processing in the traditional sense is more time-consuming and has all of the attendant dangers. According to preliminary research, microwaves may be utilized as an efficient pre-treatment for dehulling pulses that are sanitary and simple to apply while also providing the advantage of heat treatment. Additionally, thermal treatment is projected to improve the pore size of the pulses, hence decreasing the time required for water penetration and cooking (processing time required for usage as a component in food product production). Microwaves may also be used to disinfect grains and extend the shelf life of dehulled grains (Vadivambal et al. 2007).

Microwave heating would denature the protein and gums that connect the hull and cotyledon of pulses, disrupting their relationship. The exposer at which microwave energy is applied, and the dose necessary to achieve the intended effect is critical for determining the process's appropriateness. There is currently no research that explains the result of microwave treatment on chickpea dehulling and the quality criteria of the dehulled pulses.

Keeping this in mind, the current experiment was done with the research goal of examining the result of microwave treatment, viz., microwave power (power level), exposure, and dosage, on the dehulling of chickpea as well as its consequence on the processing parameters of dehulled pulses. So, the current study and experiment have described the outcome of microwave power on dehulling of chickpeas to determine the optimum condition of microwave pre-treatment on chickpeas.

Mangaraj and Singh (2009) carried out several experimental trials on CIAE dhal mill to optimize machine parameters for better chickpea milling using RSM with roller speed, emery grit size, and feed rate for improved chickpea dehulling. It was found that the dhal recovery and milling efficiencies were 73.44% and 75.53% at an emery grit size of 2.21 mm, roller speed of 10.47 m/s, and 100 kg/h feed rate.

Dronachari and Yadav (2015) studied microwave heating systems applications in pulse processing such as grain drying, cooking, microwave-assisted extraction, and disinfestations significantly affect the quality characteristics and extend storage life. Additionally, microwave heating may utilize substantially less energy for processing than traditional techniques. Today, the commercial potential of continuous flow microwave heating technologies is being explored as a pre-treatment approach for dehulling pulses, while the pulse processing industries continue to operate on a batch-processing basis.

Divekar et al. (2016) have studied the outcome of microwave treatment on dehulled pulses to decrease pulses' cooking times, including red lentils, mung bean, and pinto bean. Cooking time was the shortest for grains with an 18% moisture content and treated with 600 W for 56 s. At a 10% moisture level, the microwave treatment had a more significant impact on red lentils and mug beans than pinto beans.

Srivastava et al. (1999) investigated the impact of several pre-treatment techniques water soaking, water spraying, oil, chemical (sodium bicarbonate), and enzyme on pulses for dehulling to maximize dhal recovery with the least amount of loss. Additionally, they examined the cotyledons' protein composition (manually dehulled). After concluding that all pre-milling processes excluding sodium bicarbonate resulted in a substantial loss of protein in cotyledons associated with untreated trials, they determined that the oil treatment caused the most significant loss of protein content (3.18 percent).

Chakraverty (1994) discussed both ancient and modern techniques of pulse milling and mentioned the heating process, as conditioning in pulse processing as a pre-treatment that aids in increasing efficiency, dietary quality, and milling quality. Conventionally, two pre-treatment techniques for dehulling pulses have been used: wet and dry. After soaking in water for approximately 12 hours and heaping for approximately 16 hours, pulses are entirely combined with a paste of red earth. For 2-4 days, these grains are scattered thinly throughout drying yards. Following that, sifting is used to remove the dried red earth. Next, the grains are dehulled on a stone or emery-coated vertical chakki powered by electricity, due to numerous drawbacks, such as nutrient loss during soaking and dust adulteration of grains. Pitting extends the soaking time of cleaned and sorted grains in the dry process. These scratched grains are combined with 1% edible oil and then sun-dried for two to three days; at the end of the drying process, 2.5 percent water is sprayed and mixed in, followed by overnight tempering with heaped grain. The grains are then processed using a roller mill. This technique results in a higher yield and is widely used commercially.

Khosro et al. (2017) studied the effect of microwave treatment and machine parameters to improve dehulling. They use a tangential abrasive dehulling device (TADD). RSM optimized the result of the abrasive disk's revolving speed and grit size, microwave exposure time, and retaining time. Central Composite Design was employed and RSM-based four-factor, five-level to determine the effect of the independent variable and optimize processing condition for better dehulling efficiency. It was found that dehulling efficiency, 86.02 % and loss, 2.6% at the rotation speed, 790.44 rpm, microwave exposure time, 98s, the retaining time, 120s, and grit size, 50.

MATERIALS AND METHODS

Experimental materials

Samples

The chickpea (Desi) grains were procured from the local market of Ludhiana, Punjab, India. The grains were cleaned using cleaner cum grader and Destoner to separate all foreign matter, dust, dirt, twigs, broken and mud balls.

Determination of moisture content

The hot air oven method determined the sample's moisture content with drying at $102^0C\pm2$ for 24 h by the AOAC method (AOAC, 1990; Singh and Sahay, 1994). The average moisture content was found to be 10.04% (wb). Dehulling of chickpeas is performed at the optimum moisture content of 10% to 12% (weight basis) (Singh et al. 2004). Hence our sample was at the required moisture content, so we do not go for further dying of grain as we can achieve maximum dehulling at this moisture content.

A 3g weight of the samples was recorded on an analytical balance (Model: TB403, Dengver Instrument) of accuracy 0.001 g in triplicate, and their average value was recorded. The sample was kept into hot air oven for drying of moisture at optimum moisture range by putting in it for three different time intervals *viz.* 1 h, 2 h, and 3 h at 130ºC and for each hour, samples were weighed, and calculated moisture content as per the below mentioned formula before conducting the designed experiments.

$$\text{Moisture content (\%)} = (W_1 - W_2 / W_1 - W)*100$$

Where,

W_1 = weight in g of the petri dish with the material before drying

W_2 = weight in g of the petri dish with the material after drying

W = weight in g of the empty petri dish.

Microwave treatment

The microwave treatment was performed in a microwave oven with the help of a microwave dish. The dimension of the Microwave dish was measured, and it was recorded as a diameter of 25.9 cm. Each sample was 260g because the maximum capacity of the grain box of emery roll dehuller was 260g. The 260g sample could spread evenly on the dish surface with a grain thickness of 0.55 cm. A microwave oven is a kind of electric oven that uses electromagnetic radiation in the microwave frequency range to heat and cook food. The chickpeas were treated in the microwave at three power levels (PL), i.e., 50, 70, and 90. It was treated for varying periods, via; 1 minute, 1.5 minutes, 2 minutes, 2.5 minutes, and 3 minutes. Because beyond 90 PL and 3 minutes cooking of grain is started; hence it was not taken. The triplicate of each sample was taken in order to avoid an error. The samples were packed in plastic bags with proper coding of power level and time.

Experimental run

Each chickpeas sample was then dehulled for a time of 20 seconds. It is the time required for complete dehulling of chickpeas at 90 PL microwave power and at an exposure time of 3 minutes. Beyond this time, the powder forming, i.e., losses, increases. The dehulling was done with the help of a laboratory model emery roll dehuller (the specifications are given in Table 1 below). The digital tachometer measured the rpm of a pulley of emery roll dehuller.

The dehulling time was kept constant during the operation as 20 seconds to get maximum and complete dehulling of chickpeas after the microwave pre-treatments at different power levels (PL) viz; 50, 70, and 90 for a specified time viz. 1 minute, 1.5 minutes, 2 minutes, 2.5 minutes, and 3 minutes respectively. After dehulling, the samples were packed in plastic bags with the same coding. It was then followed by sieving and finally manual separation for obtaining the sample fraction for calculating the dehulling parameters to analyze the effect of microwave pre-treatment on chickpeas dehulling. The complete study was done triplicate to avoid error, and mean and average results were expressed.

Fractionation of dehulled chickpeas

Each sample after dehulling was divided into five fractions. and these are given as:
- Dehulled whole and split
- Hulled whole
- Broken
- Powder/Fine broken
- Husk

Sieve analysis

The sieving of dehulled chickpeas was carried out by manual power. The sieves used for this purpose were BSS sieve no. 14 for separating powder and fine broken from dehulled chickpeas, and the and sieve no. 10 used to separate husk.

Table 1: Specification of dehuller

Machine Parameters	Values
Rotation of pulley (RPM)	1122
Diameter of peripheral sieve (cm)	17.3
Diameter of abrasive roller (cm)	15
Diameter of pulley (Driven i.e., Dehuller side) (cm)	8
Diameter of pulley (Driver, i.e., motor side) (cm)	10

Manual fractionation

The remaining fraction was separated manually. The fractioseparated manually are:
- Dehulled and split
- Hulled whole
- Broken

Dehulling parameters of chickpeas

Dehulling parameters were determined in terms of dehulling yield, dhal yield, and dehulling loss.

- Dehulling yield (DeY) was defined as total whole dehulled kernels and broken kernels produced in the dehulling of pulses. The dehulling yield was calculated using the relation given by (Goyal et al. 2007).

DeY (%) =

$$\frac{weight\ of\ dehulled\ \mathrm{ker}nel\,(g)+weight\ of\ broken\,(g)}{Initial\ weight\ of\ pigeonpea}\times 100$$

- Dhal yield (DY) was defined as the yield of dehulled whole and split kernels as a percentage of initial seed weight (APQ Method 104.1, Burridge et al. 2001). Dhal yield was calculated using the relation given by (Goyal et al. 2007).

DY (%) =

$$\frac{mass\ of\ dehulled\ whole+split\ seed\ \ (g)}{Initial\ weight\ of\ pigeon\ pea}\times 100$$

- Dehulling loss (DL) was calculated as the weight fraction of the powder and fine broken relative to the initial weight of chickpea. It was calculated using the relation given by (Goyal et al. 2007).

DL (%) =

$$\frac{weight\ of\ powder\,(g)+ wt\ of\ fine\ broken\,(g)+machine\ loss}{Initial\ weight\ of\ pigeon\ pea}\times 100$$

Statistical Evaluation

All measurements were carried out in triplicate, and the results were expressed as the mean. To fit regression equations, M.S. Excel was utilized.

RESULTS AND DISCUSSIONS

Result of microwave treatment on the dehulling variable of chickpea

Dehulling yield

The dehulling yield of all chickpeas samples was recorded for each microwave power level and for each exposure time varying from 1 to 3 minutes and given in Table 2. The dehulling yield of all samples was recorded for each microwave power level, i.e., 50 PL, 70 PL, 90 PL for the exposure time of 1 to 3 minutes at an interval of 30 seconds. From the given Fig 1, it was observed that the dehulling yield showed variation at a different power level and different exposure time. The dehulling yield increases at the 50 power level from 66.68% to 71%, with 1 to 2 minutes of exposure time. As exposure time increases from 2 to 3 minutes, the average dehulling yield decreases up to 68.00%. At 70 PL, the dehulling yield increases from 68.97% to 69.48%, increasing exposure time from 1 to 3 minutes. At 90 PL, dehulling yield decreases to 68.84%, with exposure time increasing from 1 to 3 minutes. The maximum dehulling yield obtained at different power levels was 71.00% at 50 PL with 2 minutes, 69.47% at 70 PL with 2 minutes, and 70.00% at 90 PL with 1 minute.

Table 2: Result of microwave exposure on the average dehulling yield

Microwave power level (PL)	Microwave exposure time (minutes)	Average dehulling yield (%)
50	1	66.68
	1.5	66.02
	2	71.02
	2.5	68.18
	3	68.00
70	1	67.94
	1.5	68.97
	2	69.47
	2.5	68.46
	3	69.48
90	1	70
	1.5	68.71
	2	68.97
	2.5	69.74
	3	68.84

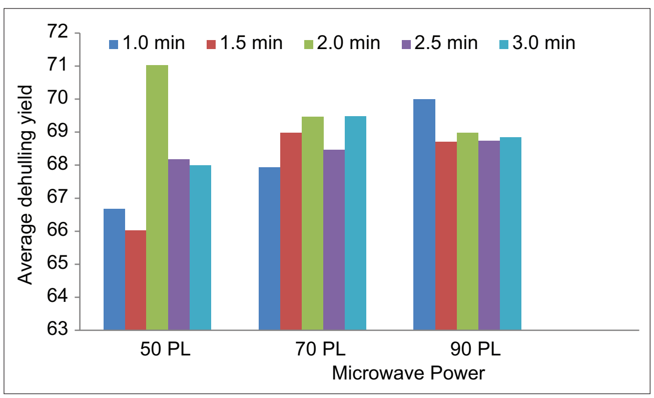

Fig 1. Result of microwave parameters on dehulling yield of chickpea

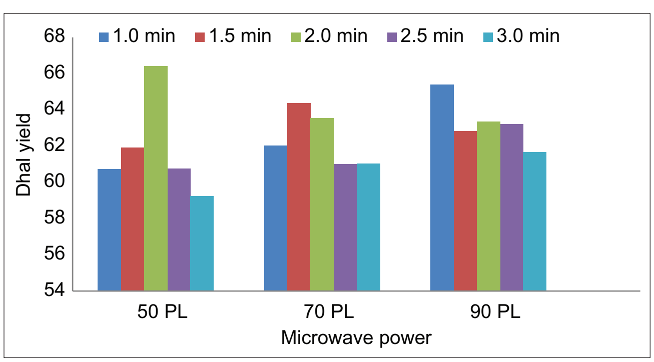

Fig 2. Result of microwave parameters on dhal yield of chickpea

It readily disintegrates grains into powder during the dehulling process, allowing for a decrease in dehulling yield at the maximum limits. The temperature of the grains reaches its maximum value at increasing microwave power and exposure duration levels. This increase in dehulling yield at lower power levels may result from the pre-treatment outcome, which causes the grains to heat up and the seed coat connections to break, allowing for simple grain splitting and seed coat removal. The average dehulling yield of chickpea at different power levels with different exposure times is exposed in the table 2

Dhal yield

The Dhal yield was documented for each microwave power level, i.e., 50 PL, 70 PL, and 90 PL for each microwave

Table 3: Result of microwave exposure on the average dhal yield

Microwave power level (PL)	Microwave exposure time (minutes)	Average dhal yield (%)
50	1	60.73
	1.5	61.91
	2	66.40
	2.5	60.18
	3	59.24
70	1	62.03
	1.5	64.35
	2	63.52
	2.5	61.00
	3	61.02
90	1	65.38
	1.5	62.81
	2	63.33
	2.5	63.2
	3	61.66

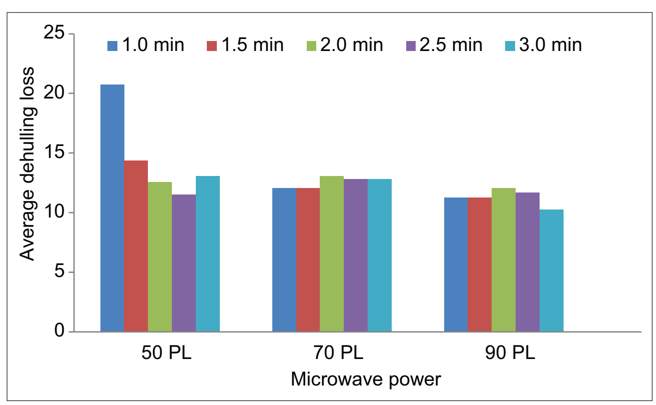

Fig 3. Result of microwave parameters on the dehulling loss of chickpea

exposure time varying from 1 to 3 minutes at an interval of 30 seconds, given in Table 3. After analysis, it was observed that dhal yield varied from 59.24% to 66.40 % at 50 PL, 61.66% to 64.35% at 70 PL, and 61.66% to 65.38% with given exposure time from 1 to 3 minutes. The difference in dhal yield for each microwave power level and exposure time has been revealed in Fig 2. It can be shown from the figure that dhal yield does not rise linearly with an increase in power level range. It was observed from the figure that the Dhal yield at 50 PL first increases from 60.73% to 66.40% with an exposure time of 1 to 2 minutes.

Further, it decreases from 66.48% to 59.24% as exposure time increases from 2 to 3 minutes. Similarly, at 70 PL dhal yield increases from 62.03% to 64.35%, and further, it decreases from 64.35% to 61.02% with exposure time for 1.5 to 3 minutes. However, at 90 PL, it was observed that the dhal yield decreases linearly from 65.38% to 61.66%, with increases in exposure time from 1 to 3 minutes. The maximum dhal yield obtained for different power levels with different exposure times was 66.40% at 50 PL with 1.5 minutes, 64.35 at 70 PL with 1.5 minutes, and the last one is 65.38% at 90 PL with an exposure time of 2 minutes. This large yield of dhal may be attributed to its pre-treatment action, which reduces the moisture content, thus disrupting the coat-cotyledon connection. A slight reduction in yield is seen at the higher power and exposer time; this may be due to grain overheating, which results in grain splitting and powdering, decreasing the yield at the higher power and exposer time. The average dhal yield of chickpea at different power levels with different exposure times is shown in Table 3 above.

Dehulling loss

The Dehulling loss for a chickpea was observed for each microwave power level and for each exposure time varying from 1 to 3 minutes and shown in Table 4. It was observed from the recorded data that the dehulling loss varies from 11.51% to 20.74% at 50 PL, 12.04% to 13.07% at 70 PL, and 10.25 to 12.04 at 90 PL. The variation dehulling loss for each microwave power level and exposure time is given in Fig. 3. Moreover, it was observed that the dehulling loss decreases from 20.765 to 10.25% with a rise in power level and exposure time. It has been seen that dehulling loss decreases with improved exposure time for a constant microwave power. The Maximum and minimum dehulling loss obtained was 20.78% at 50 PL and 10.25% at 90 PL with 1 and 3 minutes exposure time, respectively.

Table 4: Result of microwave exposure on the average dehulling loss

Microwave power level (PL)	Microwave exposure time (minutes)	Average dehulling loss (%)
50	1	20.76
	1.5	14.35
	2	12.55
	2.5	11.51
	3	13.07
70	1	12.04
	1.5	12.04
	2	13.07
	2.5	12.81
	3	12.81
90	1	11.27
	1.5	11.26
	2	12.04
	2.5	11.66
	3	10.25

As the heat impact rises with increasing power and exposure duration, the strength of the connection between the seed coat and cotyledon weakens, reducing the energy required to break the grains and thereby reducing dehulling loss. Grain that has been overheated removes seed coats easily and allows more dehulling time to remove the cotyledon altogether. The average dehulling loss of chickpea at different power levels with different exposure times is shown in the Table 4.

CONCLUSIONS

The dehulling yield improved first with a rise in the power level range. Then it decreases for all power levels. It varied from 66.02% to 71.02% at 50 PL, 67.94% to 69.48% at 70 PL and 68.84% to 70% at 90 PL during exposure time from 1 to 3 minutes. Dehulling yield increases with increasing the exposure time of microwave radiation from 1 minute to 2 minutes at the same power level. Further, it decreases with increasing exposure time up to 3 minutes due to grain cooking beyond this. The maximum dehulling yield was found was 71.02% at 50 PL with 2 minutes exposure time. Dhal yield improved with a rise in the power level range. It varied from 59.24% to 66.40% at 50 PL, 61.00% to 64.35% at 70 PL and 61.66% to 65.38% during exposure time from 1 to 3 minutes. Dhal yield increases first with increasing the exposure time of microwave radiation from 1 minute to 2 minutes at the same power level. Further, it decreases with increasing exposure time up to 3 minutes due to grain cooking. The maximum dhal yield was obtained was 66.40% at 50 PL with 2 minutes exposure time. Dehulling loss decreases with increased power level and exposure time. The dehulling loss varied from 11.51% to 20.76% at 50 PL, 12.04% to 13.07% at 70 PL, and 10.25% to 12.04%, increasing exposure time from 1 to 3 minutes. The minimum dehulling loss was obtained was 10.25% at 90 PL with 3 minutes exposure time.

CONFLICTS OF INTEREST

The authors do not have conflicts of interest.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support provided by Punjab Agricultural University, Ludhiana, for carrying out the present research work

Authors' contribution

Chandan Solanki: was involved in the design, collection of samples, laboratory work, results & analysis, and manuscript writing.

S. K. Gupta: co-supervised the research, provided a guide for sample processing, assisted with experimental sample collection and statistical analysis, and corrected the manuscript.

M. S. Alam: was involved in grant writing for the research, corrected the manuscript, and contributed to statistical analysis, writing, and English editing.

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