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# A detailed analysis on microwave pretreatment models for pulse processing

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## Abstract

In both developed and underdeveloped countries, the pulses are treated as one of the most vital constituent of human diet. Pulse milling highly focuses on the complete hull removal with little powder creation, broken, and unpeeled split formation in certain cases. The main contribution of this review is to analyze the physical and mechanical properties of different pulses with their milling strategies. It also discusses about the different types of pretreatment methods for examining the efficiency of dehulling. In addition to that, it discusses about the operating characteristics and features of various batch pre-treatment models and projects that use the microwave pre-milling treatment as a continuous pre-treatment. This work assesses the possibility of enhancing the efficiency and improved recovery of dehulling of the pulse product. This study also objects to optimize various pretreatment process parameters used for milling. Moreover, the losses that occur in the form of broken and powder are also discussed during pulse milling. In addition to that, the methods used for pulse dehulling system are evaluated for performance assessment. This review provides the comprehensive descriptions about the pulse milling procedures in the current context.

**Keywords:** Pulses, nutrition economics, pre-treatment of pulses, microwave heating, dehulling, pre-milling and continuous pre-treatment

## Introduction

According to the health and nutrition economics, the pulses has gained a significant place around the world. Pulses are the kind of dry seeds that comprises rich fiber, protein and minerals for improving body health (Belitz, Grosch, & Schieberle, 2009; Darmadi-Blackberry *et al*., 2004) [2, 7,]. In many developing regions of South Asia, pulses are considered as the main food source of people. Due to its high protein content, the nutritive values (A. Statistics, 2015; F. Statistics, 2010) [32, 33] of cereal diets are improved by adding pulses. Amino acids are the primary element in cereal proteins as there are rich in sulfur, while Lysine is the rich element in pulses protein. Also, the veal protein supplements the pulses protein with Amino acid; but the protein variation between different pulses is around 20% to 30%. Normally, the substantial amount of minerals is provided for the food by the pulses. The recent survey reports that around 67 MT of pulses could be produced by the pulses over the world during the year of 2012, in which 17 MT of pulses are produced from India. Moreover, it has the major share of 25.5% in pulses production; hence India is one of the world's largest pulse producer and consumer. Consequently, the domestic demands warrants the importation of 3.5 MT of pulses despite increased production at the year of 2013 to 2014 (A. Statistics, 2015) [32], where the pulses is about 19.27 MT.

During the pulse preprocessing, the processes such as storage, milling, and drying could create significant losses. For instance, it is stated that the loss could be 1.69 million metric tons for the overall pulse production of 15 million tons, in which 11.25 million metric ton is for milling (Dronachari & Yadav, 2015) [9]. In order to avoid these losses, it is more essential to utilize an enhanced pre-treatment methodologies as well as machineries. When compared to the traditional pre-treatment processes, the heat transfer is more beneficial with the microwave heating technology. Then, the heat generated from the microwave system spreads it to all food grains (Agu, Tabil, Mupondwa, Cree, & Emadi, 2021) [1] and the microwave is a kind of electromagnetic spectrum that lies in the frequency ranges from 300 MHz to 300 GHz.

When the dielectric materials absorb the microwaves, the energy is given up by the microwave resulting with temperature rise. Moreover, the output power of the microwave system increases the heating speed of di-electric material processing. In microwave heating, the higher degree of heating is obtainable (Wei *et al.*, 2020) [42], but many food applications require an increased heat rate control. Agreeable reactions of biochemical and physical natures may not take place at a very high speed of heating. When the amount of water in the food source is high, the dielectric loss factor ε is also high, which is defined as the extent of converting an electric field into a heat energy. The shape of food source is also one of key factor for obtaining uniform heating, if the shape is random, it leads to local heating. Similar to that, the food materials with varying corners and shapes could also result in non-uniform heating. Then, the conversion of microwave heating methodology (Tosun, 2016) [35] is represented as follows:

$$P = 2\pi f E^2 V \varepsilon'' \varepsilon_0 \qquad (1)$$

Where, $P$ indicates the power, $E$ is the strength of electric field (V/m), $V$ defines the volume of food material $m^3$, $f$ is the frequency in terms of Hz, ε" indicates the dielectric loss factor, and ε0 indicates the permittivity of free space i.e. 8.854 x 10-12 F/m. During the pre-treatment of pulses, the microwave heating is applied to minimize the post-harvest losses at the time of storage, cooking, milling and drying.

Also, the microwave is mainly used to dry the pulses with reduced time consumption and increased quality of product. The microwave heating is a type of pre-milling treatment, which is mainly used to minimize the amount of time for processing, and to increase the efficiency. Although, microwave based cooking is not suitable for mass cooking, and is more appropriate for cooking with small quantity of food specifically used in households. Furthermore, disinfestation with microwave heat is a non-chemical method and mainly used for heating insects at high temperature, because the insects are normally having high moisture contents whereas, the dried food is slightly warm or unaffected.

Conventionally, several studies are highly concentrating on utilizing the energy from microwave for the pre-treatment of pulses. The main contribution of this paper is to conduct the detailed review related to the continuous pulses pre-treatment processing strategies, where the microwave pre-treatment is mainly concentrated. This paper studies various conventional pre-treatment processes for getting the clear idea and reasons about why the continuous pre-treating process is more sought. Then, the clear overview about the use of microwave heating methodology is presented with its applications for effectively processing the pulses. Finally, the microwave pulse pre-treatment process is compared with some other convention pre-treatment strategies. Fig 1 shows the general flow of processing the pulses.

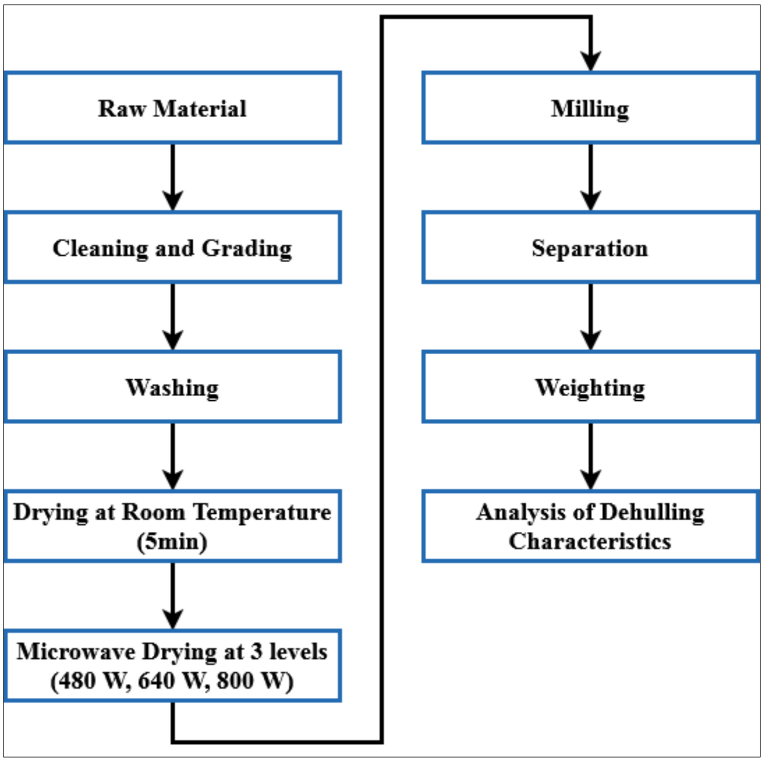

**Fig 1:** Flow of the pulse processing (Dhruw & Raj, 2019) [8] Milling Strategies

This section discusses about the pre-milling treatments used for improving the quality and production of pulses with reduced time slot (Mangaraj, Agrawal, Kapoor, & Kulkarni, 2004) [20].

After cereals, the legumes/pulses are the second most essential food source around the world, which is mainly belongs to the family of Leguminosae including more than 18000 species of plants. These plants are edible dry seeds and it does not includes Glycine max (Soybean) and Arachis hypogea (groundnut), which are few oil bearing seeds grown majorly for edible oil extraction as green peas. Normally, the green beans are considered as the non-dried or fresh, and not all legumes are considered as the pulses but, all pulses are treated as the legumes. The type of pulse-grown pulses is determined and influenced by the geographic region, in which chick peas, lentils, beans, and field peas are the most commonly used grown pulses in Canada. Similarly, the mung bean is the widely used pulse in China, and the black-eyed peas (Cowpea) is the major pulses crop highly used in Southern United States. In the developing world, there is an increased utilization and interest in pulses, because the pulses crop is one of the good source for micronutrients and fibre (Vitamins and minerals), energy (carbohydrate) and protein. Ongoing studies on production and processing technologies incidences of food allergies on the raised, in demographics (age, racial diversity), balance/variety demand increasing, changes in customers' preferences, and the health and nutritional benefits are the contributing factors. Over the past 40 years, it is analyzed that around 40.8 MT of pulses are produced at the year of 1961, and about 60.9 MT pulses are produced at the year of 2008, which is nearly 19% of increase in the production between these years.

Moreover, the legumes, fermented legumes like dhokla and wadi are the fermented products of chickpea; spouted pulses; canned pulses; dry pulses (such as dehulled, whole and/or split), which are all some common forms of pulses based foods. Similar to that, other forms of pulse products have been developed with the added values of roasted pulse seeds, extruded pulses products, quick-cook dehydrated pulse, and micronized/infra-red heat-treated pulses. Baked goods, infant food, fried snacks, flours, extruded snacks, bread, batters, tortillas, noodles, and pasta are types of pulses milled into flours, and are customarily prepared with non-pulses flours with formulation. During processing, it is necessary to include water in the whole pulse seed at some point, and is one of the critical aspect of all these pulse products. To produce an acceptable micronized whole pulses seed product, it is studied from the literature that tempering the moisture content of the seed with the small quantity of water to predetermine the moisture content is widely used. The roasted pulses snack processing also requires tempering, because it is also one of the essential step in pre-treatment. To improve the yield of dehulled product materials (that is, dehulling efficiency), tempering of pulses is a necessary step in the milling and dehulling processes, which determines that whether the hulling process is economically feasible or not. Then, it is the kind of quality factor used by the pulses exporters, processors and breeders. In many industrial and scientific communities, developing the food products with the pulses and seeds require an adequate hydration at the time of pre-treatment.

Normally, the germs and cotyledon are highly protected at the time of pre-treatments (Round, Rigby, MacDougall, & Morris, 2010) [27]. For increasing this type of protection, the pre-milling treatments are mainly utilized to eliminate the husk, and to obtain the seed coats with any losing of germs and cotyledon materials (Tiwari & Singh, 2012) [34]. The main reasons for using the pulses for this type of treatment are listed in below:

- Improves the quality of splits
- Reduction in breakage
- Ease to milling
- Loosen the hull

### *Pre-Milling Treatments*

Normally, milling is defined as the process of reducing the larger size of materials to the smaller size, and in other term, milling of pulses is defined by the removal of seed coat. In Asia and Africa countries, the most common milling operations are the production of split seeds by the cleavage of two cotyledons and production of polished seed (dehulling) by the removal of seed coat. Specifically, the quality properties are highly derived by the pulse exporters, processors, and breeders for dehulling pulses, in which producing the dehulled seeds is one of the most significant aspect of pulse processing [29, 30]. Some other parameters like improved digestability, palatability, storability and reduced cooking time are obtained by using the dehulling pulse. Moreover, the dehulling operation could be maximally reduced from 80% to 90% with the potential of anti-nutritional polyphenols of the seed coat.

Conventionally, there are different pre-treatment methods are used for pulses, which includes the followings:

1. Wet pre-treatment
2. Chemical pre-treatment
3. Enzymatic pre-treatment
4. Hydrothermal pre-treatment
5. Oil pre-treatment
6. Continuous pulse pre-treatment

Wet pre-treatment is considered as one of the oldest pre-treatment methodology used for pulse treatment, and is developed before milling. Also, it involves the processes of seed-soaking in water for six to eight hours, mixing with red earth slurry (3%), drying under sun for two to four days tempering with eight to twelve hours, and removing red earth. In India, the water pre-treatment technique is mainly used for commercially processing the chickpea. The key benefit of using the water pre-treatment methodology is, it efficiently facilitates the cotyledon splitting and dehulling with negligible breakage. Nonetheless, the wet pre-milling treatment influences the quality of cooking adversely depends on the weather condition and requires intense labor. The chemical pre-treatment method provides various chemical aqueous solutions such as NaCl, Na2CO3, NaHCO3, NaOH, and acetic acid. The chemical pre-treatment with NaHCO3 shows the significant enhancement in dehulling efficiency, where the optimization of pigeon pea process is analyzed. Generally, the Enzymes are vital classes of globular proteins that exist biologically. Enzymes function as biocatalysts and speed up biochemical reaction rates without being consumed in the process. The property of enzymes differentiate them from catalysts based on its selective and specific actions. Every enzyme has a different function from other; that is, no two enzymes have the same specific action. This makes enzymes as the valuables substances to both the engineers and chemists. Nonetheless, enzyme pre-milling treatment for easy and efficient pulse dehulling is still restricted to the laboratory stage. The main purpose of utilizing the enzymes is to improve the oil recovery from canola through partially hydrolyzing the cell walls.

The Central Food Technological Research Institute (CFTRI) India has reported that heating could facilitate the pigeon pea dehulling with the standardized process. The hydrothermal pre-treatment consists of the pitting operation, conditioning and application of oil for six to eight hours, grain heating at 120 to 180 °C in Louisiana State University, drying as well as conditioning for five to six hours in the drying bin. Then, the optimal efficiency of dehulling is about 74% reported for microwave heating at around 972 J/g. However, the microwave and hydrothermal pre-milling treatment methods are only used for improving the pulse dehulling, and are yet to be commercially applied. The oil pre-treatment process consists of pitting operation at the moisture content of 10 to 12%. Applying oil (preferably edible oil) at 0.1 to 1% (w/w), dry the seeds under the sun for two to five days, adding the needed water amount for increasing the moisture content by 2 to 5%, temper the seeds in stacked form for twelve to eighteen hours. Finally, sun-dry to remove about 90% moisture and then mill the pulses. To dehull pulses that are difficult to mill requires repeated passing of the pulses through the abrasive mill. Additionally, edible oils are believed to help weaken the bond between the cotyledon and coat of the seed or dissolve the gums. Nonetheless, there is no explanation of edible oils, when loosening the bond between the cotyledon and hull.

## Dielectric properties of grains

In the present days, there are many studies highly focusing on measuring the dielectric properties of grains for ensuring the increased utilization of energy from microwave, which is further used for different types of unit operations to process the pulses (S. O. Nelson, 1987) [23]. It includes the seed treatment, control of insect, pre-milling methods, and drying, which are used to enhance the dehulling quality. With the development of thermal treatment with energy from microwave, the dielectric properties data have become crucial, and is more essential for computing the uniformity in heating. Similarly, certain factors such as temperature, bulk density, moisture content, and frequency may affect the dielectric properties of wet pulses, where the frequency is directly proportional to the dielectric constant (S. Nelson, Bartley, & Lawrence, 1998) [22].

When heating with microwave, non-uniform heating prevails regardless of the food substance. While heating samples, the differences in temperature noticed were large within the samples that were being heated during heating of different model foods, meat, ready-to-eat meals, vegetables, and grains with the microwave. Several authors have proposed a few approaches for reducing uneven heating intensity in microwaves. In (Fung & Cunningham, 1980) [14], the authors suggested combining microwave heating with traditional heating, leading to increased uniform food heating and bacteria destruction. Food components of thickness more than 25 to 30 mm are not supposed to be stacked; instead, they should be placed beside one another while food substances of thin slices can be stacked edge to edge; also, the uniform thickness should be maintained be ensured anytime it is achievable. The authors in (Ohlsson & Thorsell, 1984) [26] reported that it is possible to enhance the uniformity in heating by manipulating the geometry of the food. The efficiency of utilizing metal bands (Ho & Yam, 1992) [16] in enhancing the uniformity in microwave heating, an efficient approach to samples of cylindrical shapes under limitations, shows that additional experiments must describe metal shielding effect under food substances requirements with different geometries, sizes, and dielectric properties. (Chandrasekaran, Ramanathan, & Basak, 2013; Ryynänen & Ohlsson, 1996; Vilayannur, Puri, & Anantheswaran, 1998) [28, 6, 39] suggested manipulating the uneven heating like package design, formulation of ingredient, heat cycle control, microwave oven design, combining all of the above to enhance uniformity in microwave heating. Temperature uniformity can be obtained by combining for a short time, high power heating, and product holding or low power heating subsequently for a longer time (Fakhouri & Ramaswamy, 1993) [10].

The loss of moisture during heating with microwave is one of the main factors in designing the processes for using microwave heating to heat foods. Non-uniform heating, like overheating of the edges, increases the loss of moisture (Ni, Datta, & Parmeswar, 1999) [24]. For oats, rye, and barley heated for 500 W, 400 W, 300 W, and 200 W, the loss of moisture for moisture content (14%) of the grains mentioned above at 28 seconds of exposure time were (1.5, 1.2, 0.9, 0.6), (2.2, 1.7, 1.2, 0.8) and (3.5, 2.3, 1.6, 1.1) %, respectively. The loss of moisture in oats rose by 4.5. 3.2, and 1.9% with an increase in the time of exposure and moisture. The loss of moisture is directly proportional to the time of exposure and power for oilseeds and cereals. From the result of the analysis of variance conducted, it was observed that the loss of moisture is significantly affected by the time of exposure, power, and moisture content. This shows that the larger the initial moisture content, the more significant moisture loss in the oilseeds and cereal. Comparing moisture loss for sunflower, oats, rye, and barley indicates that moisture loss was least in sunflower followed by barley, rye, and oats. The study carried out by (Hamid, Kashyap, & Cauwenberghe, 1968) [15] for inset controlling with the use of the energy from microwave indicated that the wheat moisture content fell by less than 1% for exposure higher than the corresponding time of exposure of the total mortality of the three wheat insects. The experiment conducted by (Vadivambal, Jayas, & White, 2008) [37] lowered the moisture content of wheat by 2% and obtained 100% mortality of the wheat insect using the energy from microwave. More considerable loss of moisture in oats at each power level and time of exposure can be explained because the husk of the oats holds most of the water; thus, it is lost easily during heating.

## Analyzing the current status and usage of microwave heat treatment

Using microwave energy for sterilization and pasteurization processes to destroy pathogens efficiently and considerably lower the time of processing with minor damage to the total quality of the food in liquid form compared to the conventional methods (Hao Feng, Yin, & Tang, 2012) [13]. Utilizing microwave heating to process food like baking, cooking, and blanching greatly influences the nutrient-preserving quality of the food. Different researchers have investigated the effect of the energy from microwaves on wheat and the baking, chemical, and physical properties of dried wheat. The report of the researchers indicates that the overall protein content of food is not affected by the heat in the microwave oven at a temperature of 90°C, however, the wet gluten content, as well as the germination, were affected progressively at temperatures more than the range of 60 and 66 °C respectively (Campana, Sempe, & Filgueira, 1993) [5]. In their conclusion, the authors stated that protein content was not affected; however, the gluten functionality was changed gradually when exposure increased. Additionally, the study of (Velu, Nagender, Rao, & Rao, 2006) [38] using Kjeldahl's method showed that the protein content of foods was not changed when dried using a microwave. The study of (Vadivambal, Jayas, & White, 2007) [36] showed that a difference in temperature of around 70 °C existed as well as a few changes in the structure of the protein and starch were observed between the cold and hot parts of the barley sample pre-treated with energy from microwave. The traditional methods for the pre-treatment of pulses are currently ineffective in removing or reducing the anti-nutritional factors. The microwave pre-treatment process presents alternative and more processing techniques to reduce heat liable and heat-stable anti-nutrients. Microwave heat increased duration effectively activates anti-nutrients such as oligosaccharides, trypsin inhibitor activity, total oxalate, hydrogen cyanide, and phytic acid. The mortality of insects in green gram, pigeon pea, and chickpea varies directly with the extended time of exposure in the microwave and inversely reduces exposure time in the microwave (Singh, Singh, &

Kotwaliwale, 2012) [30]. The germination and feasibility of the seeds of green gram, pigeon pea, and chickpea were affected by exposure in the microwave and the power level at 5% significant level and concludes that power level decreases viability and germination of the seeds of each pulse. The dehulling process, called primary processing, converts the whole seeds into pulses. It is an essential operation of post-harvest handling of pulses and thus takes part in the use and processing of pulses in people's daily diets. Pre-treatment influences the dehulling process and consequently the pulses yield. Different milling methods, i.e., dry and wet milling, CFTRI method, Pantnagar process (chemical and enzymatic process), CIAE method. By using different dehulling methods with pre-treatment, an amount of 20-25% of milling losses takes place because the pulse milling industry is running with batch processing, involves excessive material handling, and much dust is generated inside the mill, which can be reduced by introducing continuous type processing system. This review introduces using a continuous microwave heating system at different power levels as pre-treatment before dehulling of pulses helps in reducing dehulling time, increases dehulling efficiency, reduces cooking time, less energy consumption improves nutritional quality, and also uses as a non-chemical alternative for post-harvest insect control in dried agricultural commodities.

## Applications of microwave heat system in pulse processing

As a novel technology, food drying with microwave has opened opportunities for possible broad application due to reduced drying and product quality improvement. However, industries are yet to adopt this approach due to a few associated engineering issues designing the drying chambers in microwaves (Nijhuis *et al*., 1996) [25]. That is, non-uniform heating arises from the unevenly distributed microwave field in the cavity resulting from sinusoidal microwaves superposition (Zhang, Tang, Mujumdar, & Wang, 2006) [44], an intrinsic property of microwaves. Drying with microwave relies on the volumetric heating mode facilitated by electromagnetic radiation at 2,450 or 915 MHz (Schubert & Regie, 2006) [29]. The fast-drying and heating of food in microwave results from the loss of moisture in the food product to dielectric heating leading to varying fast energy coupling. The benefits of drying with microwave stem from the product heating in the inside, which causes the development of internal vapor pressure, which in turn drives out the moisture from the product within a short time of drying to an efficiency of about 25 to 90% (H Feng, Tang, Cavalieri, & Plumb, 2001) [12] as well as increasing the rate of drying to 4-8 times (Brygidyr, Rzepecka, & McConnell, 1977) [4] and enhanced quality in comparison to convective drying. The non-uniformity in the surface temperature of wheat, canola, and barley observed in a microwave dryer operated industrially on a pilot scale at five different power levels and two different exposure times were studied by (Manickavasagan, Jayas, & White, 2007) [21]. They observed a non-uniform pattern of drying and that the mean surface temperature after pre-treatment with microwave for wheat (73.4 to 108.8 °C), canola (65.9 to 97.5 °C), and barley (72.5 to 117.5 °C). The study of (Soysal, Ayhan, Eştürk, & Arıkan, 2009) [31] was performed to assess the microwave drying in continuous and batch modes at two separate power outputs for the microwave (697.87 W and 597.20 W) using two identical microwave–convective dryers. Their result indicated that the continuous mode drying treatment had the least drying time while the batch drying treatment took a long time; however, the quality of the product from the continuous dryer was poor. On the other hand, the quality of the product from the batch drying process was better. Microwave heating is broadly combined chiefly with hot air drying (Andrés, Bilbao, & Fito, 2004) [2]. In the first drying stage, microwave heating results in a dried product with high porosity due to rapid evaporation after heating. Additionally, the application of microwaves in the final drying phase can reduce shrinkage and the overall time of drying. An operation that has seen considerable success in food dehydration is microwave-assisted vacuum drying, and much research on this technique has been carried out (Lin, Durance, & Scaman, 1998) [19]. In heat to dry foods with high sensitivity, the combined fluidized bed drying, and microwave heating, particularly with the spouted bed, has seen so much success (H Feng, Tang, & Cavalieri, 1999) [11]. Based on dielectric heating of grain insects that is a relatively poor electricity conductor and relies on materials' electrical properties, microwaves have been used for killing these insects. The exposure of pulse beetles to microwave radiation of about 2450 MHz at different levels of power and time of exposure for the attainment of 100% mortality of the insects at 20, 40, 60, 80, and 100% levels of power for determining the milling and cooking properties, germination, and viability of green gram, pigeon pea, and chickpea are investigated (Yadav, Anand, Sharma, & Gupta, 2014) [43]. The result indicated that the germination and viability properties of the seed were affected by the level of power and time of exposure in the microwave. Additionally, the level of power was seen to vary inversely with the viability and germination of each pulse. It was also observed that the insects in the mobile state moved toward the surface from the inner part of the nutrient medium when exposed to microwave heating. When insects and dry foodstuffs were mixed in a microwave, the possibility of hating the insects to a very high temperature is high due to the significant moisture content of the insects, whereas the dryer foodstuffs are left sparingly warm or unaffected (Wang & Tang, 2001) [41].

## Results and Discussion

This section discusses about the results of various pulse pretreatment models by using different evaluation metrics. Based on the analysis of existing works (Dhruw & Raj, 2019) [8], the results are analyzed and investigated in this part for identifying the most suitable method used for an efficient pre-treatment of pulses. Table 1 depicts the global requirements of pulse production from the year of 2015 to the future of 2100 (Lal, 2017) [18] with respect to the parameters of world population, production rate, anticipated crop, and required land area. Based on this forecasting analysis, it is identified that the pulse requirement has been gradually increased with reduced consumption of land area. Also, its production rate may attain a significant growth according to the world's population.

**Table 1:** Pulse production requirement analysis over the world

| Year | Worldwide Population | Prerequisite production | Anticipated Crop | Required land area |
|---|---|---|---|---|
| 2015 | 7.4 | 338 | 0.70 | 450 |
| 2020 | 7.5 | 342 | 1 | 340 |
| 2030 | 8.1 | 370 | 1.25 | 296 |
| 2040 | 8.6 | 392 | 1.5 | 248 |
| 2050 | 9.7 | 443 | 1.8 | 246 |
| 2100 | 11.2 | 511 | 2.15 | 238 |

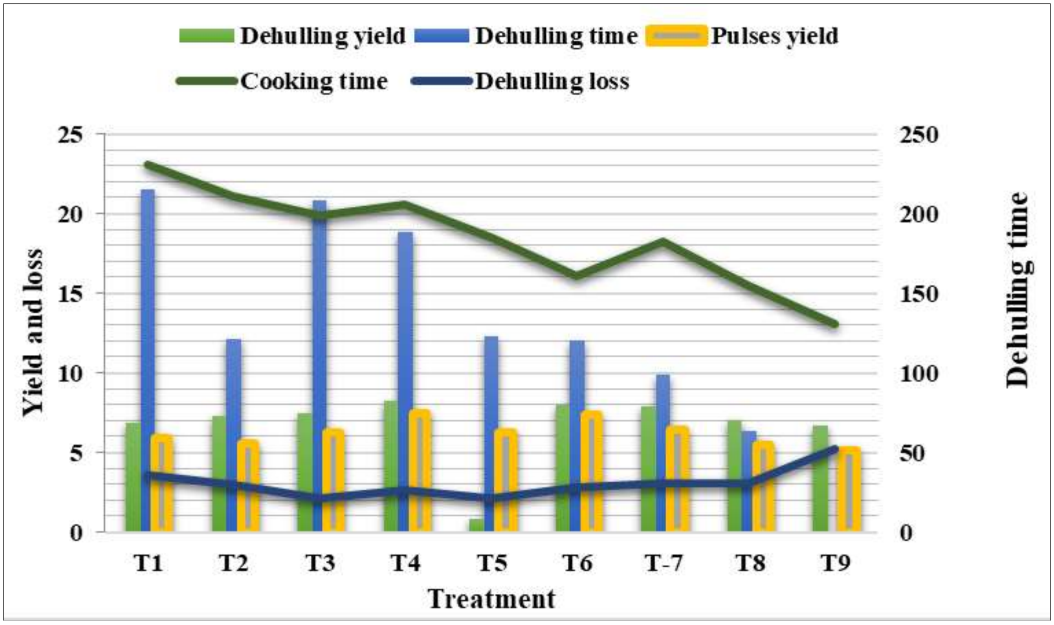

**Fig 2:** Analysis of microwave pre-treatment for pigeon pea

Fig 2 shows the effects of microwave pretreatment methodology for processing the pigeon pea pulse, where T1 to T9 indicates the level of control. In this graph, the bar charts indicate the dehulling yield, dehulling time, pulses yield, and the line charts indicate the cooking time and dehulling loss (Vishwakarma *et al*., 2018) [40]. Based on these results, it is observed that the dehulling loss could be efficiently reduced with the use of microwave pre-treatment. Also, the cooking time is gradually reduced with for each level of microwave energy. Similar to that, Fig 3 compares the optimal treatment and controlling model with respect to the percentage of improvement over control. From the evaluation, it is identified that the dehulling time (13%), dehulling yield (6%), pulses yield (14%), dehulling loss (31%), and cooking time (20%) of optimal pretreatment is better than the control model. Table 2 shows the effects of various pretreatment models (Kumar, Poshadri, Shiva Charan, Raghuveer, & Kumar, 2019) [17] used for processing the pulses with respect to the measures of dehulling efficiency, recovery, unhusked, husk and powder in terms of %. The different types of models taken for this evaluation are control, Water Soaking (WS) with Sun Drying (SD), Water Soaking (WS) for 11 hours with Sun Drying (SD), and Oil Pretreatment (OP), Tampering (TA), Water (W), Spraying (S), with Sun Drying (SD).

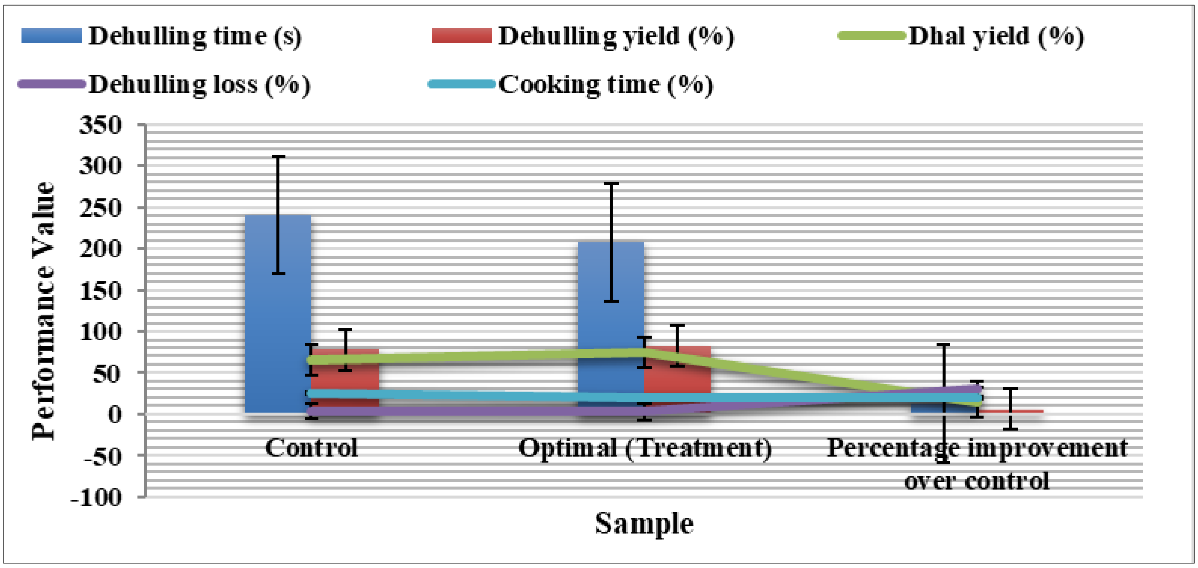

**Fig 3:** Comparative analysis between optimal treatment and control sample

**Table 2:** Comparative analysis of various pretreatment models

| Pre-treatment models | Dehulling efficiency (%) | Recovery (%) | Unhusked (%) | Husk and powder (%) |
|---|---|---|---|---|
| Control | 49.47 | 43 | 39 | 16.9 |
| WS+SD | 96.5 | 73.5 | 5.3 | 21 |
| WS 11H + SD | 97.8 | 76 | 4.2 | 20 |
| OP +TA+W+S+SD | 99 | 76 | 3.8 | 20 |

## Conclusion

Pulse milling has risen in popularity from researchers all over the world, it's seen a lot of development in terms of pre-treatment methods and the creation of the dehulling machine.

Pitting, pre-treatments, conditioning, and dehulling are all part of the dehulling process for pulses in a system of convex spherically grinding machines. This pitting operation is crucial in the pulse milling operation since it affects how effective the pre-treatment is in achieving better milling results. The chemical structure of the gums between both the cotyledon and the hull has a significant impact on the milling process efficiency. In general, the gums in easy-to-mill pulses are made up of hygroscopic polysaccharides, whereas the gums in difficult-to-mill pulses are made up of minerals like manganese, copper, and zinc, as well as uronic acid, and pectin in large amounts. Pre-treating pulses with edible oils is a common commercial practice. Despite this, the significance of oil in loosening the link between the cotyledon and hull remains uncertain. Pre-treatment with enzymatic enzymes improves dehulling efficiency, although more research is needed. Dehulling of enzyme-treated target grains took less time than dehulling of water-treated grains used in traditional milling. Grains that had been pre-treated with enzymes had brighter hues than those that had not been.

The chemical wet and hydrothermal pre-treatment procedures did a decent job of pre-treating the pulses before dehulling, but the labour intensiveness, power consumption, and non-commercial use of the techniques are still concerns. As a result, a continuous procedure for pre-treating pulses before dehulling is required. Also, this paper discusses the successful application of microwave heating technology in pulse processing as a continuous method for pulse pre-treatment. Microwave heating has a substantial impact on quality metrics and improves storage life in pulse processing such as grain drying, cooking, microwave-assisted extraction, and disinfestation. Furthermore, compared to traditional methods, microwave heating may consume much less energy for cooking and drying. Pulse processing necessitates pre-treatments such as heat treatment; microwave pre-treatment gives certain nutritional benefits. Because pulse processing firms are still using batch pre-treatment processing, the possibility of continuous flow microwave heating technologies as a pre-treatment approach for dehulling pulses on a commercial scale requires additional exploration.

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