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Process optimization of dried ginger (*Zingiber officinale*) pulp

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Abstract

Ginger (*Zingiber officinale*) is a popular food and spice. With the increase in consumption of ginger-based products, there will also be an increase in the production of their waste pulp. Therefore, this study aimed to evaluate the quality of ginger pulp to optimize its fibre content for food and industrial application. The study investigated the effects of different process variables on the quality of ginger pulp using the response surface methodology to optimize its process conditions. Under these optimized conditions, the following optimized values were obtained: water activity of 0.3827, minimum bulk density of 0.0769 g/mL, maximum bulk density of 0.1296 g/mL, maximum ash content of 0.64%, lowest water retention capacity of 4.295 g/g, highest water retention capacity of 7.32 g/g, lowest oil binding capacity of 2.973 g/g, maximum oil binding capacity of 4.663 g/g, and fibre content of 69.13%. In addition, the fibre content of the dried ginger pulp was found to be higher compared to other natural sources of food fibres. Therefore, the dried ginger pulp fibre was recommended as a natural source of food fibres.

1. Introduction

In the Philippines, ginger (*Zingiber officinale*) is a popular food and spice. It has many applications in food preparation, bakery products, toiletries, perfumes, meat products, wine, soft drinks, spices, and medicine (Deshmukh *et al.*, 2014). It has many potentials, particularly in the field of medicine, as evidenced by its anti-inflammatory properties (Choi *et al.*, 2013; Rupasinghe and Gunathilake, 2015; Wiastuti *et al.*, 2016), blood pressure-lowering, cholesterol-lowering, antiplatelet aggregation, chemopreventive, and hypoglycaemic properties (Rupasinghe and Gunathilake, 2015). It is also composed of many antioxidants like polyphenols, vitamin C, beta-carotene, flavonoids, and tannins (Shirin and Jamuna, 2010).

Because of the health benefits of consuming ginger, it is commonly used in the production of ginger tea which is a health beverage having 86.33% antioxidant activity (Ahmad *et al.*, 2016). Ginger tea has been studied for its effectiveness in managing morning sickness among prenatal mothers and cancer patients (Alexander and Williams, 2016; Purneswari *et al.*, 2018; Shiradwade and Satvekar, 2019; Das *et al.*, 2020); providing relief for dysmenorrhea (Crasta *et al.*, 2019); and for fetal development (Wilkinson, 2000).

With the increase in processing and consumption of ginger-based products, there will also be an increase in the production of waste pulp after production. During ginger tea processing, following aqueous manual extraction of its juice, 50±5% of the ginger is turned into pulp and is wasted or discarded which can be a potential source of fibre. Fibre is mainly found in fruits, vegetables, whole grains and legumes. Fibre is a form of carbohydrate that can't be absorbed and digested by the body (Farooqui, 2015). There are two types of dietary fibre: soluble and insoluble. Soluble fibre dissolves in water forms viscous gels and helps in lowering cholesterol levels while insoluble fibre which is insoluble in water facilitates good bowel movement. Intake of high fibre has many health benefits maintaining body weight by promoting weight loss, preventing obesity, reducing appetite, lowering the risk of diabetes by reducing glucose absorption and improving insulin sensitivity lowering blood sugar levels (Dhingra *et al.*, 2012; Farooqui, 2015), promoting heart health and reduce risk of heart diseases (Dhingra *et al.*, 2012), reduce risk of cancer by binding carcinogens, balancing intestinal pH, and enhancing fermentation in the intestine, maintaining normal gastrointestinal function, relieves constipation by improving movement of food in the digestive system, and lowering of blood pressure (Dhingra *et al.*, 2012; Farooqui, 2015).

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Ginger is high in fibre with 23.5 and 25.5% insoluble and soluble fibre, respectively, and is one of its most important quality parameters (Shirin and Jamuna, 2010; Jayashree *et al.*, 2014). Because of this, the pulp can be processed and utilized as fibre fortification for food or other industrial products. The structure of the fibre matrix can alter dramatically during heating and processing. These modifications impact the kind and structure of fibre found in foods and are critical to our knowledge of fibre's role in the diet. Boiling chickpeas significantly enhanced insoluble dietary fibre (24%) and total dietary fibre (25%); however, soluble dietary fibre (obtained by subtracting total and insoluble fractions) decreased in comparison to raw legume values (Perez-Hidalgo *et al.*, 1997). During heating, the cellulose and pectin of fresh carrots dissolve, and their cell walls grow thinner and more brittle when boiled for 15 to 4.5 mins. It was hypothesized that the cellulose was either freed from the surrounding material or hydrolyzed during the cooking process. The rise in cellulose value seen on a dry weight basis might be attributed to cellulose release, which makes it more accessible for examination (Simpson and Halliday, 1941; Mattheé and Appledorf, 1978). The development of resistant starch may have contributed to the rise in the DF content of cooked potato (RS). The name "RS" refers to a starch fraction that is resistant to the activity of amylolytic enzymes. It may be formed by submitting foods to heat and/or dehydration, which gives the starch molecules a more ordered structure and makes them less sensitive to enzyme digestion (Thed and Phillips, 1995). Soaking reduced soluble sugar (9.8%) while increasing starch (7.3 percent) and soluble fibre (9.8%) compared to untreated beans (16.9%). There was an increase in soluble sugar (1.5%) and a decrease in thiamine (81.7%), starch (24.6%), soluble fibre (16.6%), and nitrogen (2.9%) content in cooked beans (Barampama and Simard, 1995).

Therefore, there was a need to study the quality properties of this waste product to optimize its processing conditions prior to utilization for food and industrial applications. Process variables focused on the use of water as a solvent during the pre-treatment to ensure the immediate use of the samples for food without dealing with any residue from any reagent or catalyst. The study's main goal was to optimize the process conditions in the production of dried ginger pulp. The effect of boiling time, soaking time and drying temperature on the water activity, bulk density, water retention capacity, and oil binding capacity of the dried samples was investigated.

Therefore, this study aimed to optimise the cooking time, soaking time, and drying temperature on the production and properties of dried ginger pulp.

2. Materials and methods

2.1 Preparation of materials

Fresh ginger bought from a local market was washed and cleaned using running water. The samples are then sliced and sized down using a blender pulsed at a low setting and then at a high setting for 1 min with a 1:1 ratio of ginger to water. The ginger juice was manually extracted using cheesecloth to separate the pulp. The pulp was then analyzed for baseline data (moisture, water activity). Approximately 1 kg of ginger pulp was added to 9 L of distilled water and boiled at different durations (10, 20, and 30 mins) with constant stirring. Afterwards, the pulp from the mixture was extracted using a cheesecloth to remove excess water. After the boiling process, one part of ginger pulp was soaked in five parts of distilled water at different soaking durations (60, 120, and 180 mins) with stirring every 15 mins. After soaking, the pulp was again extracted using cheesecloth to remove the water. The ginger pulp after being boiled, and soaked was dried in an oven at different drying temperatures (40, 50, and 60°C) until a moisture level of less than 10% was achieved. Afterwards, the dried ginger pulp was packed in airtight containers and stored at 4°C prior to analysis (Shirin Adel and Jamuna, 2010; Jayashree *et al.*, 2014; Sangwan *et al.*, 2014).

2.2 Physicochemical analysis

2.2.1 Moisture content

A sample weight of 100 g was used for moisture content determination. Samples were dried using a laboratory oven at 105°C for 2 hrs. Then the sample was cooled at room temperature in the desiccator. The sample was weighed and dried for another 2 hrs. The process was repeated until the difference in weight between two successive dryings of 2 hrs was less than or equal to 2 mg (Shiradwade and Satvekar, 2019). Calculations was done using Equation 1.

$$\mathrm{MC\,(wb)} = \frac{\mathrm{Wi-Wf}}{\mathrm{Wi}} \times 100 \quad (1)$$

MC (wb) is moisture content of dried ginger pulp wet basis (%), Wi is the initial weight of ginger pulp (g), and Wf is the final weight of ginger pulp after drying (g).

2.2.2 Water activity and bulk density

Water activity was tested using a water activity meter. For the bulk density, dried ginger pulp was poured into a 10 mL graduated cylinder. The ratio of the weight of the dried ginger pulp and its volume was considered the bulk density.

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2.2.3 Ash content

Ash comprises the mineral content that was present in the sample, which can be determined by igniting unknown amounts of dried material in a muffle furnace. The dried material obtained from the determination of moisture in a crucible dish was ignited on a blue flame of a burner till the smoke was given off. The porcelain/ crucible dish was then heated in a muffle furnace maintained at 500±5°C for 2 hrs. It was cooled in a desiccator and weight was taken (Gupta *et al.*, 2016). Percent ash was calculated using Equation 2.

$$Ash\ (\%) = \frac{W_1}{W_2} \times 100 \quad (2)$$

W_1 is the weight of dried ginger pulp after ignition (g), W_2 is the initial weight of dried ginger pulp (g).

2.2.4 Oil binding capacity

A 500 mg sample with known dry matter content was weighed for the dry sample weight and mixed with 10 mL of vegetable oil in a centrifuge tube. It was allowed to equilibrate for 24 hrs at room temperature and then centrifuged at 4,900 rpm for 30 mins. Then the supernatant was decanted and the residue was weighted. The OBC was calculated using Equation 3.

$$Oil\ binding\ capacity\ (g/g) = \frac{W_2}{W_1} \quad (3)$$

Where W_1 is the weight of dried ginger pulp after centrifugation (g), and W_2 is the initial weight of dried ginger pulp (g).

2.2.5 Water retention capacity

Approximately 1 g of the sample was hydrated with 15 mL of distilled water in a centrifuge tube at room temperature. After 24 hrs, the sample was centrifuged at 4,500 rpm for 20 min. Then the supernatant was decanted and the residue was weighted. The WRC was calculated using Equation 4.

$$Water\ retention\ capacity\ (g/g) = \frac{W_2}{W_1} \quad (4)$$

Where W_1 is the weight of dried ginger pulp after centrifugation (g), and W_2 is the initial weight of dried ginger pulp (g).

2.2.6 Crude fibre

A 2 g of dried ginger pulp was weighed and added with 50 mL 0.25 N sulfuric acid. The solution was boiled for 30 mins and filtered through a Buchner funnel using filtering cloth. The residue was washed with boiling water and drained by suction. The collected residue was then added with 50 mL 0.313 N sodium hydroxide and boiled for 30 mins. The mixture was filtered using a dried and pre-weighed ashless filter paper. The residue was washed with boiling water, then with ethanol. The filter paper containing the residue was transferred to a pre-weighed crucible and dried at 105°C for at least 3 hrs then cooled and weigh. The crucible containing sample was ignited at 500°C for at least 2 hrs until white or grayish ash was obtained. The sample was then cooled and weigh prior to calculation of crude fibre using Equation 5.

$$\text{Crude fibre}\ (\%) = \frac{W_2 - W_3}{W_1} \times 100 \quad (5)$$

Where W_1 is the initial weight of dried ginger pulp (g), W_2 is the weight of oven dried ginger pulp, and W_3 is the weight of ash (g).

2.4 Statistical analysis

Boiling time, soaking time, and drying temperature was the three factors to be considered in the study. The Box-Behnken Design under the Response Surface Methodology was used. Analysis of variance (ANOVA) was used to determine if there was a significant difference among treatment means. Minitab 18.1 was used to perform the analysis. The three (3) uncoded independent variables to be used that correspond to the boiling time, soaking time, and drying temperature are shown in Table 1.

Table 1. Uncoded values of the independent variables.

Run Order	Boiling Time, min	Soaking Time, min	Drying Temperature, °C
1	20	180	60
2	10	120	40
3	20	120	50
4	10	120	60
5	10	60	50
6	20	60	60
7	30	60	50
8	20	120	50
9	30	120	60
10	30	180	50
11	30	120	40
12	10	180	50
13	20	120	50
14	20	180	40
15	20	60	40

3. Results and discussion

3.1 Effect of process variables on the physicochemical properties of ginger pulp

Summarized in Table 2 the experimental results for the physicochemical properties of ginger pulp (water activity, bulk density, ash content, water retention capacity, oil binding capacity, and crude fibre) under

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Table 2. Experimental design of process in coded and actual variables and values of experimental data.

Run	a_w	Bulk Density, g/mL	Ash Content, %	Water Retention Capacity, g/g	Oil Binding Capacity, g/g	Crude Fibre
1	0.627	0.101	0.120	6.495	4.281	19.35
2	0.598	0.103	0.225	7.175	3.538	36.04
3	0.756	0.109	0.175	6.158	4.284	59.06
4	0.451	0.091	0.346	6.064	3.941	26.22
5	0.513	0.082	0.332	5.542	3.312	23.13
6	0.489	0.109	0.319	6.272	3.388	53.65
7	0.524	0.121	0.402	7.576	3.123	24.42
8	0.560	0.115	0.259	6.905	3.584	44.21
9	0.657	0.119	0.276	5.311	4.052	48.26
10	0.584	0.119	0.432	7.097	3.852	38.77
11	0.589	0.101	0.342	5.705	4.453	42.65
12	0.528	0.123	0.182	5.801	3.305	18.9
13	0.535	0.106	0.323	6.642	4.324	56.67
14	0.545	0.106	0.571	3.457	4.600	70.34
15	0.518	0.111	0.386	3.892	4.147	58.03

various treatment conditions.

3.1.1 Water activity

Water activity (a_w) of the ginger pulp fibres ranges from 0.451 to 0.756. Ginger pulp treated with 10 mins of boiling time, 120 mins of soaking time, and 60°C drying temperature showed the lowest water activity of 0.451, while samples treated at median boiling time, soaking time, and drying temperature showed the highest water activity value (Table 2).

An analysis of variance was used to determine the significant effects of process variables on water activity, results indicated that lack of fit was not significant (P >0.05) for water activity, which means that the model was adequate for describing the influence of process variables on the response. However, the coefficient of determination, R^2, was found to be 56.19% for the responses. Overall, the condition with 10 mins of boiling, 60 mins of soaking, and 60°C of drying temperature gives the minimum water activity of 0.3827. All observed water activities had a value of less than 0.9, where the majority of microorganisms stop growing, while the optimal value was lower than 0.50, where no microbial proliferation will occur, providing stability against microbial growth and other damage (Beuchat, 1981; Blancas-Benitez *et al.*, 2015; Fontana, 2000).

3.1.2 Bulk density

The bulk density of the ginger pulp fibres ranges from 0.082 to 0.123 g/mL with the highest at 0.123 g/mL when the ginger pulp was boiled for 10 mins, soaked for 180 mins (3 hrs), and dried at 50°C. When subjected to the same treatment except for the soaking time, the lowest value of 0.082 g/mL was obtained. The results revealed that increasing the soaking time from one to three hrs increased bulk density by 150% (Table 2). The contour plot and 3D surface plots are shown in Figures 1 and 2. The plots present the effect of the treatment conditions (boiling time, soaking time, and drying temperature) on the bulk density. According to the response surface model results, bulk density decreases as drying temperature increases, whereas density increases as soaking and boiling duration increases.

Analysis of variance was used to determine the significant effects of process variables on bulk density, results indicated that lack of fit was not significant (P >0.05) for bulk density, which means that the model was adequate for describing the influence of process variables on the response. The coefficient of determination, R^2, was found to be 77.07% for the responses indicating that the data fit the statistical model. Overall, the condition with 10 mins of boiling, 60 mins of soaking, and 60°C of drying temperature gives the minimum bulk density of 0.0769 g/mL, while 30 mins of boiling, 60 mins of soaking, and 57.98°C of drying temperature gives the maximum bulk density of 0.1296 g/mL. Bulk density is a crucial factor in package design and transportation volume computation since it lowers packaging and shipping costs (Jittanit *et al.*, 2011; Kalyankar *et al.*, 2016).

The optimized value was lower compared to the report of Jittanit *et al.* (2011) on tamarind powder with a bulk density of 0.478 to 0.816 g/mL. It was also lower compared to custard apple pulp powder with a maximum bulk density of 0.81 g/mL (Jittanit *et al.*, 2011; Shrivastava *et al.*, 2021). Powders with higher densities offer an advantage over products with lower densities because they may be stored in greater numbers in smaller containers, however, powders having low densities offer

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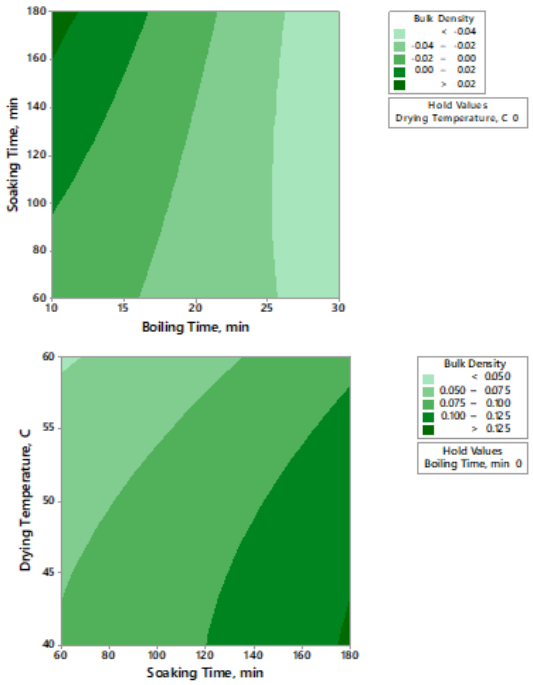

Figure 1. Contour plot of bulk density vs boiling time, soaking time, and drying temperature.

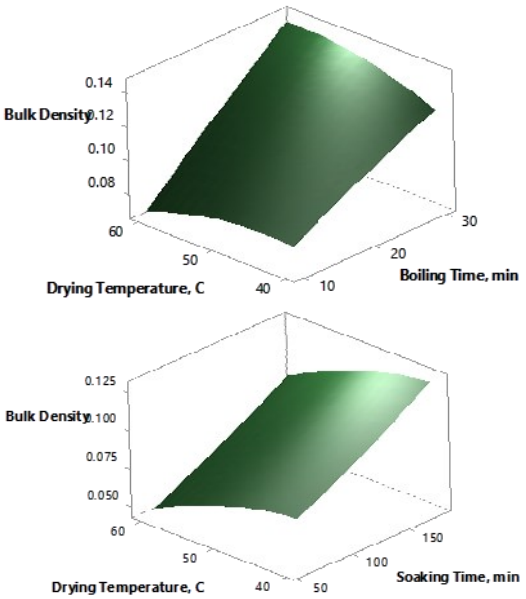

Figure 2. Surface plot of bulk density vs boiling time, soaking time, and drying temperature.

good dispersibility making them a good material for supplements (Ghavidel and Prakash, 2006; Cynthia *et al.*, 2015; Liu *et al.*, 2018). The distribution and size of the particles in a food also have a significant impact on its bulk characteristics and it might affect the dried ginger pulp as the product doesn't undergo any form of size reduction after drying (Shrivastava *et al.*, 2021).

3.1.3 Ash content

Ash comprises the mineral content which was present in the sample (Gupta *et al.*, 2016). Low ash content in the pulp indicates that the total inorganic mineral is low (Oloyede, 2005). The percent ash content of the ginger pulp was lowest with treatments using 20 mins of boiling time, 180 mins of soaking time, and a 60°C drying temperature, with a value of 0.12%. The highest ash content of 0.571% was found using 20 mins of boiling time, 180 mins of soaking time, and dried at 40°C. When the results were compared, it was discovered that increasing the drying temperature reduced the ash content of the ginger pulp. The results showed a large difference in comparison to fresh ginger and pulp having 0.0229% and 0.0266% ash content, respectively (Table 2). As the P-value of lack-of-fit was greater than α = 5% then it was not statistically significant or the test does not detect any lack-of-fit. Therefore, the model adequately describes the functional relationship between the experimental factors and the response variable. However, the coefficient of determination, R^2, was found to be 65.55% for the responses.

Overall, the condition with 30 mins of boiling, 180 mins of soaking, and 40°C of drying temperature gives the maximum ash content of 0.64%. After optimization, an increase of 0.61 to 0.62% was calculated between the fresh samples (ginger rhizome and pulp) and dried samples. However, the optimized value of ash was found to be lower compared to cassava pulp and mung bean flour with 3.76% and 5.203 to 5.477% ash content, respectively (Liu *et al.*, 2016; Liu *et al.*, 2018). Ash contents of ginger powder dried in shade, solar dryer, oven and microwave were also higher ranging from 3.3 to 3.6%, respectively (Sangwan *et al.*, 2014).

3.1.4 Water retention capacity

Water retention capacity is defined as the weight of the sample divided by the weight of the sample after centrifugation. As a result, this number reflects how much water is retained in the hydrated fibre following the application of an external force, or how much water is absorbed by the fibre matrix (Raghavendra *et al.*, 2004; de Escalada Pla *et al.*, 2007). In terms of water retention capacity, treatments composed of 30 mins of boiling time, 60 mins of soaking time, and 50°C drying temperature showed the largest value of 7.576 g/g, while treatment combinations of 20 mins of boiling time, 180 mins of soaking time, and dried at 40°C showed the lowest value 3.892 g/g (Table 2).

An analysis of variance was used to determine the significant effects of process variables on water retention, results indicated that lack of fit was not significant (P >0.05) for water retention capacity, which means that the model was adequate for describing the influence of process variables on the response. However, the coefficient of determination, R^2, was found to be 44.84% for the responses.

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Overall, the condition with 22.31 mins of boiling, 180 mins of soaking, and 40°C of drying temperature gives the lowest water retention capacity of 4.295 g/g. While condition with 30 mins of boiling, 109.7 mins of soaking, and 53.33°C of drying temperature gives the highest water retention capacity of 7.32 g/g. The result of the process optimization of the dried ginger pulp showed a higher value compared to the result of Raghavendra *et al.* (2004) and Huang *et al.* (2018) which ranges from 4.2 to 5.5 g/g for sugar beet pulp powders and 5.4 g/g for coconut dietary fibre (Raghavendra *et al.*, 2004; Huang *et al.*, 2018). It was also higher compared to soy hulls and some legume fibres namely: pea hull, lentil, chickpea hull, and mung bean hull (Dalgetty and Baik, 2003; Tiwari and Cummins, 2011; Liu *et al.*, 2016; Huang *et al.*, 2020). The fibre's chemical, physical, and microstructural qualities determine how much water it can absorb at its maximum capacity. Additionally, these characteristics are crucial for determining the effectiveness of fibre fractions derived as bulking, swelling, and/or thickening agents in formulations or meals with a relatively high water activity (Raghavendra *et al.*, 2004; de Escalada Pla *et al.*, 2007). This is true as the samples are not size-reduced after drying, which results in larger fibre particles, which may affect its water retention capacity as smaller fibre particles may lower the absorption of water (Tiwari and Cummins, 2011; Huang *et al.*, 2020).

3.1.5 Oil binding capacity

Another useful characteristic that aids in the stabilization of high-fat goods and emulsions is the ability to bind oil. The hydrophobic bonding capability of the fibre molecules is what causes them to retain fat or oil (Tiwari and Cummins, 2011). For the oil binding capacity of dried ginger pulp, results showed a value of 4.6 g/g after using 20 mins of boiling time, 180 mins of soaking time, and a 40°C drying temperature. The lowest value of 3.123 g/g oil binding capacity was found using 30 mins of boiling time, 60 mins of soaking time, and dried at 50°C (Table 2). The contour plot and 3D surface plots are shown in Figures 3 and 4. The plots present the effect of the treatment conditions (boiling time, soaking time, and drying temperature) on the oil binding capacity. Based on the results of the response surface model, an increase in soaking time decreases oil binding capacity while an increase in boiling time increases oil binding capacity.

An analysis of variance was used to determine the significant effects of process variables on oil binding capacity. The coefficient of determination, R^2, was found to be 81.04% for the responses indicating that the data fit the statistical model. As the P-value of lack-of-fit was

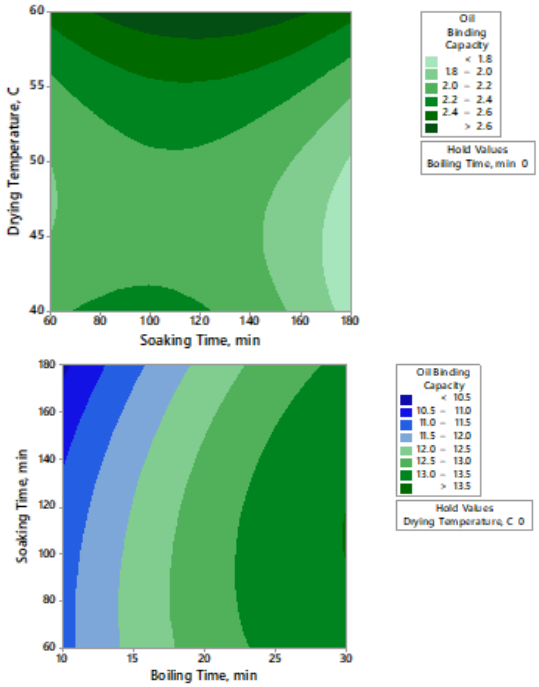

Figure 3. Contour plot of oil binding capacity vs boiling time, soaking time, and drying temperature.

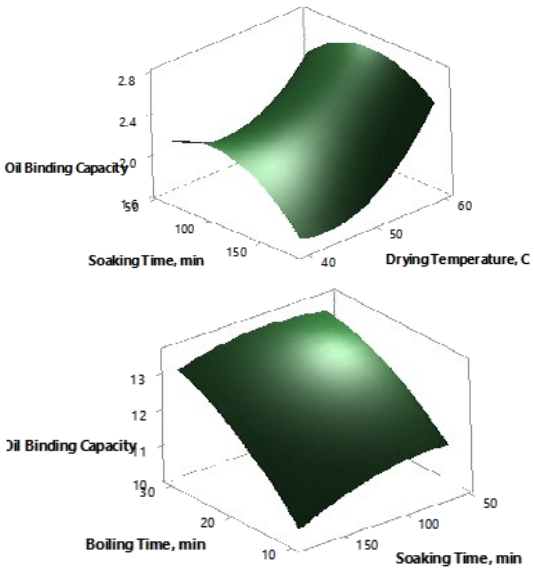

Figure 4. Surface plot of oil binding capacity vs boiling time, soaking time, and drying temperature.

greater than α = 5% then it was not statistically significant or the test did not detect any lack-of-fit. Therefore, the model adequately describes the functional relationship between the experimental factors and the response variable.

Overall, the condition with 30 mins of boiling, 60 mins of soaking, and 56.97°C of drying temperature gives the lowest oil binding capacity of 2.973 g/g. While condition with 25.96 mins of boiling, 147.27 mins of soaking, and 40°C of drying temperature gives the maximum oil binding capacity of 4.663 g/g. Compared to other sources of fibres, the optimized value of the oil binding was lower than soy hulls but higher than most legume fibres e.g. pea hull, lentil hull, chickpea hull, mung bean hull (Dalgetty and Baik, 2003; Tiwari and

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Cummins, 2011; Liu *et al.*, 2016; Huang *et al.*, 2020). The high oil binding capacity of the ginger pulp fibres may be a result of the high crude fibre content of the samples and the size of its particles also decrease its bulk density and increase its water absorption (Tiwari and Cummins, 2011; Huang *et al.*, 2020).

3.2 Effect of process variables on the crude fibre

Fibre as the main parameter of the study ranges from 18.90 to 70.34%. The highest crude fibre value of 70.34% was obtained by boiling for 20 mins, soaking for 180 mins, and drying at 40°C, while the lowest value of 18.90% was obtained by boiling for 10 mins, soaking for 180 mins, and drying at 50°C. The results showed a huge difference in comparison to fresh ginger and pulp having 1.46% and 3.08% crude fibre, respectively. This shows the extent of the effect of the process variables in increasing the fibre content of the ginger pulp.

The contour plot and 3D surface plots are shown in Figures 5 and 6. The plots present the effect of the treatment conditions (boiling time, soaking time, and drying temperature) on the crude fibre content. According to the response surface model results, increasing soaking time increases crude fibre while increasing boiling time reduces crude fibre.

An analysis of variance was used to determine the significant effects of process variables on crude fibre, results indicated that lack of fit was not significant (P >.05) for crude fibre, which means that the model was adequate for describing the influence of process variables on the response. The coefficient of determination, R^2, was found to be 84.24% for the responses indicating that the data fit the statistical model. The quadratic term Boiling Time*Boiling Time was significant at 5%, therefore the response surface features a curvature. The reason for the higher significant effect of boiling to the crude fibre may be due to the alteration of dietary fibre that causes an increase of insoluble fibre and a decrease of soluble fibre (Veena *et al.*, 1995; Tiwari and Cummins, 2011). Domestically, boiling is a standard technique for removing antinutritional elements and preparing grains and legumes for consumption. Depending on the amount of heat treatment used, boiling may change the amount of dietary fibre present. Additionally, boiling will remove the indigestible complex sugars (Tiwari and Cummins, 2011).

Overall, the condition with 21.5152 mins of boiling, 163.03 mins of soaking, and 40°C of drying temperature gives the maximum crude fibre content of 69.1304%. The optimized value was higher compared to ginger powder dried using different drying methods with fibre content ranging from only 4.9 to 5.6% (Sangwan *et al.*,

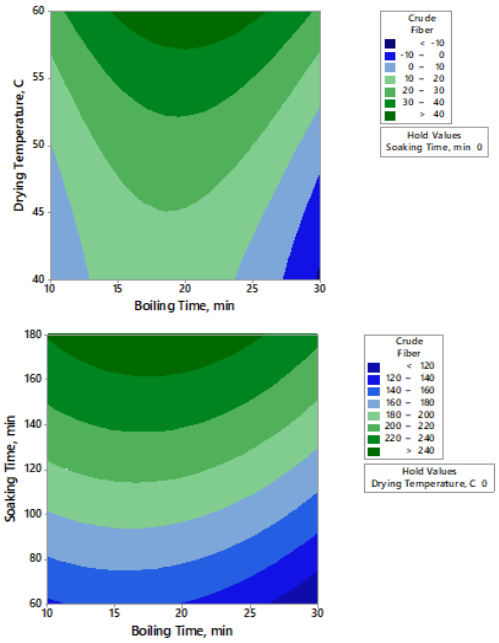

Figure 5. Contour plot of crude fibre vs boiling time, soaking time, and drying temperature.

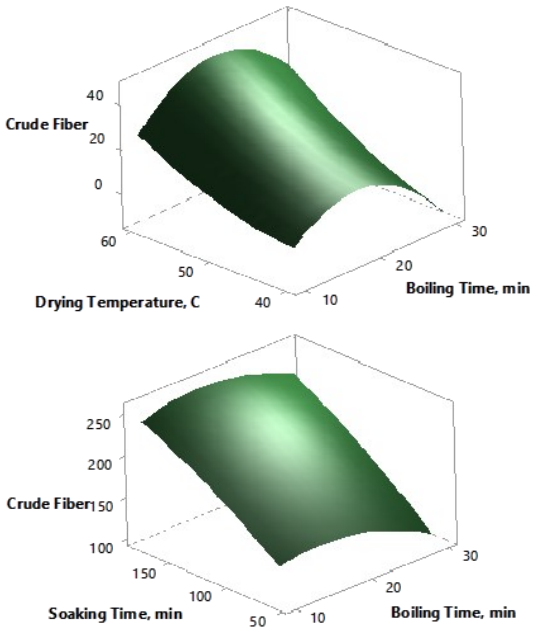

Figure 6. Surface plot of crude fibre vs vs boiling time, soaking time, and drying temperature.

2014). In addition, the optimized fibre content of ginger pulp was higher compared to the following natural sources of fibres namely: psyllium husk, barley, oat bran, soy bran, soya meal, carrot fibre, apple, banana, orange, citrus pulp, cauliflower, white cabbage, wheat bran, coconut, and unripe pulp of papaya. In addition, taking 36 to 55 grams of dried ginger pulp, it will provide the daily reference intake of fibre for individuals aged 19 to 30 years old (Schweizer and Würsch, 1979; Caprez *et al.*, 1986; Lee *et al.*, 1992; Trinidad *et al.*, 2001; Trumbo *et al.*, 2002; Raghavendra *et al.*, 2004; Trinidad *et al.*, 2006).

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3.3 Optimization of process variables

During optimization of the process conditions, all independent variables were kept within range and the described targets for each response are presented in Table 3. Based on the result of the analysis, the optimal condition of 26.56 mins boiling time, 170.30 mins soaking time, and 41.82°C drying temperature was obtained with a predicted value of the crude fibre content of 60.07%. The water activity, ash content, bulk density, water retention capacity, oil binding capacity, and crude fibre of the dried ginger pulp under the optimized conditions are presented in Table 3.

Table 3. Simultaneously optimized process conditions with target and experimental values of responses.

Responses	Target	Experimental Values
Water Activity	Minimum	0.563
Ash Content	Maximum	0.506
Bulk Density, g/mL	Maximum	0.106
Water Retention Capacity, g/g	Maximum	5.064
Oil Binding Capacity, g/g	Maximum	4.489
Crude Fibre, %	Maximum	60.071

4. Conclusion

According to the results of the study, the optimized value for boiling time is 26.56 mins. Furthermore, the optimum values for soaking time, and drying temperature are 170.30 mins, and 41.82°C, respectively. Lastly, the fibre content of the dried ginger pulp was found to be higher compared to other natural sources of food fibres.

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