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Microwave-assisted drying of stingless bee (tetragonula biroi) pollens

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Abstract—
The main objective of the study was to evaluate the effect of microwave drying to the quality of stingless bee pollens. A microwave oven was modified to have an air circulating facility for drying purposes. Fresh bee pollens were analyzed for baseline data. The bee pollens were microwave dried in different power outputs (119W, 336W, and 700W), and then these were characterized to determine the drying characteristics and changes in its quality.

The microwave dryer has an overall dimension of 300 x 450 x 500mm (LxWxH). Results showed that 700W power output has the best performance compared to 336W and 119W in terms of drying time (5 mins), drying capacity (1.8kg/hr), and moisture reduction rate (108.421%/hr).

Based on the analysis, fresh bee pollens has 12.07% moisture, pH of 4.04, water activity of 0.622, 16% w/w of protein, 1.1mg/100g of vitamin E, and 0.118mg/100g of β-carotene. After drying, the 336W treatment has the highest protein content of 16.3% w/w compared to 700W with 16.1% w/w. In vitamin E, 119W has 0.95mg/100g which was lower than the value of fresh samples while in 700W and 336W, vitamin E increases with 2.8 and 1.7mg/100g, respectively. All treatments show an increase in β-carotene with 700W as the highest (0.226mg/100g) and 336W with the lowest (0.174mg/100g).

Index Terms— *drying, microwave, pollen, stingless bee*

I. INTRODUCTION

Bee pollen is a rich source of nutrients needed by the body, it is even considered as one of nature's complete foods. It is a good source of protein, vitamins, minerals, and antioxidants that our body needs. It is rich in B vitamins that are essential for good brain health. Protein, which is one of the major components of bee pollen, is important for good skin, and bone and muscle development [1].

Bee pollen is collected by worker honeybees during foraging. For honeybees, honey provides them their carbohydrates for energy, but bee pollen provides all the nutrients that honey can't provide. Because there is a peak in pollen production, humans take the opportunity to collect their excess bee pollen during this time.

Honey has always been the main product from honeybees. Like honey, bee pollens can also be produced for human consumption and pharmaceuticals. Bee pollen is a perishable commodity and exposure of fresh bee pollens to moisture will promote deterioration. Because the bee pollen will be processed and stored as food or supplement, the need for an efficient drying technique is required to maintain the nutritive value of the product [2][3].

After collection the bee pollens are normally stored in the freezer to prolong its shelf life. But considering that bee pollens will be packed dry in bottles, sachet or in capsules, drying is a better option.

Drying of honeybee pollen is essential in improving storage life and meeting market requirement. The need for drying prevents mold formation and eventual deterioration.

Air drying is not enough to meet market requirement and it can expose the product to contaminants therefore using dryers is essential. Also, the cold storage system throughout its distribution chain is not always available and dried pollen is currently the requirement for sales.

Stingless bee pollens take around three weeks of air drying and 5 days using an oven dryer (dried at 45ºC) before the product is ready for sales. The amount of time to dry the product can cause delay in the marketability and longer exposure during air drying can cause food contamination. Drying time also influence power consumption as longer drying consumes more energy. This will result to higher production cost affecting the income of the bee producers or processors.

As fresh bee pollens have considerable amount of moisture, it can be a good breeding ground for bacterial and fungal growth. Drying, which is a process of preserving bee pollens, has been practiced for many years now, but a study shows that dehydration of pollen causes reduction of some of its key nutrients [1].

Microwave drying, another method of dehydration, has been studied and reported to have less drying time in comparison with conventional drying without or less effect to the nutritive value of the commodity. This, in essence, reduces energy consumption while increasing production [4].

In this study, the effect of microwave energy to the drying time and nutritive quality of honeybee pollen was analyzed to determine the applicability of using this technique for enhancing the drying quality of bee pollens. The fabricated microwave dryer that was used for this study was assessed for possible adoption of bee keepers to the technology.

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II. Methodology

A. Modification and Evaluation of the Microwave Oven

The design of the microwave dryer was based on the existing commercial microwave oven. Inner parts of the microwave oven including the oven cavity, vacuum tube, and controls were maintained for the fabrication of the microwave dryer. Air circulation facility like exhaust fans and air intake was added to the oven together with the stainless outer shell.

The microwave dryer was evaluated using the following parameters:

1) Drying Capacity

The drying capacity of the dryer was computed using (1) [5].

$$Dc = \frac{Wi}{Td} \qquad (1)$$

Where Dc is the drying capacity (kg/h), Wi is the initial weight of test material (kg), and Td is the actual drying time (h).

2) Moisture Reduction Rate

The moisture reduction rate of the microwave dryer was computed using (2) [5].

$$MCr = \frac{MCi - MCf}{Td} \qquad (2)$$

Where MCr is the moisture reduction rate (%/h), MCi is the initial moisture content of test material (%), MCf is the final moisture content of test material (%), and Td is the actual drying time (h).

3) Percentage Recovery Output

Percentage recovery is defined as the ratio of final weight of dried output to initial or fresh weight of sample material expressed in percent using (3) [6].

$$PR = \frac{Wf}{Wi} \text{ x } 100 \qquad (3)$$

Where PR is the percentage recovery (%), Wi is the initial weight of test material (g), and Wf is the final weight of test material (g)

B. Characterization of Fresh and Microwave Dried Stingless Bee Pollens at Different Microwave Output

Fresh stingless bee pollens were bought at a bee farm in Sorsogon City. Samples were refrigerated until further processing. Prior to drying, the frozen bee pollens were allowed to warm up to room temperature conditions [7]. The cleaning of the pollen was done by manually removing foreign materials e.g. dead bees and bee's legs. The bee pollens were mixed to attain homogeneity of samples. After the cleaning process, the samples were then analyzed for moisture content, pH, water activity, and nutrient content.

Nine 150 grams of honeybee pollen was dried using the microwave dryer at 700W, 336W and 119W microwave power output. The drying time was determined until 4% moisture content was reached. Final weight of the sample with 4% moisture content was computed using (4) [5][8].

$$Wf = \frac{Wi\ (100-MCi)}{(100-MCf)} \qquad (4)$$

Where Wf is the final weight of the sample (g), Wi is the initial weight of the sample (g), MCi is the initial moisture content (%), and MCf is the final moisture content (%).

The testing was done in three replicates except for the protein, vitamin E and beta carotene content which was sampled by composite sampling. The treatment with the highest nutrient value was selected for the comparison analysis of the microwave and oven drying of stingless bee pollens.

1) Moisture Content

Moisture content of the stingless bee pollens was determined by drying the samples using laboratory oven (MEMMERT) at 103 °C ± 1 °C for 24 hours. Test was done in triplicate and calculated using (5) [5].

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$$MC = \frac{Wi - Wo}{Wi} \times 100 \quad (5)$$

Where MC is the moisture content (% wb), Wi is the initial weight of sample (g), and Wo is the oven dry weight (g).

2) pH

The pH level of stingless bee pollen was measured using a bench top professional pH meter (TRANS INSTRUMENTS) at the Ramon Magsaysay Center for Agricultural Resources and Environmental Studies (RM CARES), Central Luzon State University (CLSU), Science City of Muñoz, Nueva Ecija, Philippines

3) Water Activity

Water activity was tested using a water activity meter (NOVASINA) at the Agriculture and Food Technology Business Incubator (AFTBI), CLSU, Science City of Muñoz, Nueva Ecija, Philippines

4) Protein, Vitamin E and Beta Carotene Content

Analysis for beta carotene, protein and vitamin E content of the stingless bee pollens was done by SentroTek in Mandaluyong City. Protein content was determined using Kjeldahl method while vitamin E and beta carotene content was measured using high performance liquid chromatography.

C. Determination of Required Microwave Power Output for the Microwaving of Stingless Bee Pollens

The protein, vitamin E and beta carotene content of the microwave dried stingless bee pollens were evaluated based on Recommended Energy and Nutrient Intakes (RENI) for Filipinos. The vitamin A content of the stingless bee pollens was computed from the beta carotene content of the sample using a vitamin converter [9]

D. Experimental Design

The drying performance of the microwave dryer and qualities of the stingless bee pollens dried at different microwave power output (119W, 336W and 700W) were laid out in a Completely Randomized Design. The effect of the microwave energy to the drying performance of the microwave dryer and quality of the bee pollens were evaluated using one-way analysis of variance. Least significant difference test at 5% level of significance was used for the comparison of treatment means. Analysis was done using Statistical Tool for Agricultural Research (STAR) application.

III. Results and Discussion

A. Microwave Dryer

The microwave dryer (Fig 1) has dimensions of 300 mm length, 450 mm width, 500 mm high and weighs 18 kg. The dryer was fabricated with some parts from the existing microwave oven like vacuum tube, controls and turn table. A 1.5 mm THK stainless steel sheet was used for the outer cover, top and back portion of the drying chamber. It also has stainless steel air ducts equipped with four 120 mm exhaust fans as provision for the discharge of moisture removed from the material. The recorded inside air velocity was 2 m/s which is above the minimum required velocity of 0.2 m/s. This is similar to the air velocity used for the microwave drying of apple slices having good moisture diffusivity [5] [10].

Fig 1. Microwave dryer

1) Drying Capacity

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Drying capacity was the amount of stingless bee pollens that can be dried, in kilogram, in one hour drying period. The effect of different microwave power levels to the drying capacity of stingless bee pollens was shown in Table I.

Table I. Performance of the microwave dryer at different microwave power outputs

Power Levels	Drying Time, hr	Drying Capacity, kg/hr	Moisture Reduction Rate, %/hr	% Recovery
119 W	19.33	0.008	0.42	91.62
336 W	0.24	0.61	33.04	91.60
700 W	0.08	1.80	108.42	90.69

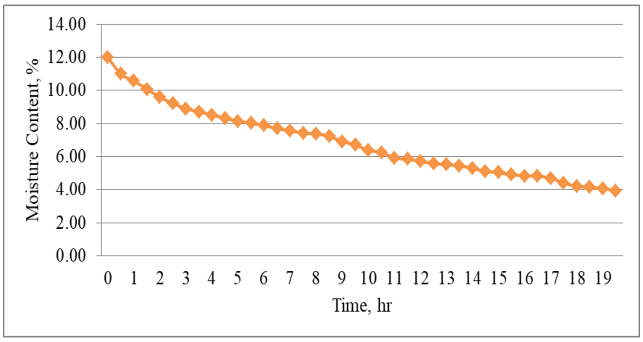
Comparison among means of the drying capacity as affected by microwave power output revealed that there was a significant difference in drying capacity in in all treatments means. The 700W treatment shows the highest drying capacity of 1.80 kg/hr followed by the 336W treatment with 0.62 kg/hr drying capacity. The 119W treatment shows the lowest drying capacity of 0.008 kg/hr.

2) Moisture Reduction Rate

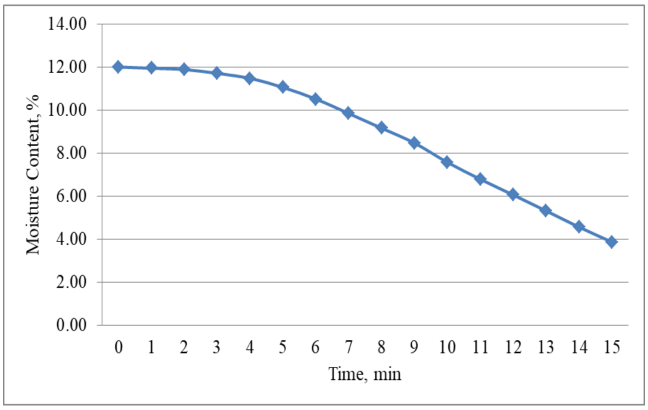
The moisture reduction rates for microwave drying of stingless bee pollens as affected by different microwave output were shown in Table I.

At 336W and 700W, drying time was faster and only requires less than an hour of operation with 0.24 and 0.08 hours, respectively. The 119W treatment had significantly longer drying time than the other 2 treatments of 19.33 hours to reach the desired level of moisture of around 4%.

The drying characteristic of the stingless bee pollen during microwave drying at different microwave power output was represented as drying curves plotted in moisture content against drying time as shown in Fig. 2.



(a)



(b)

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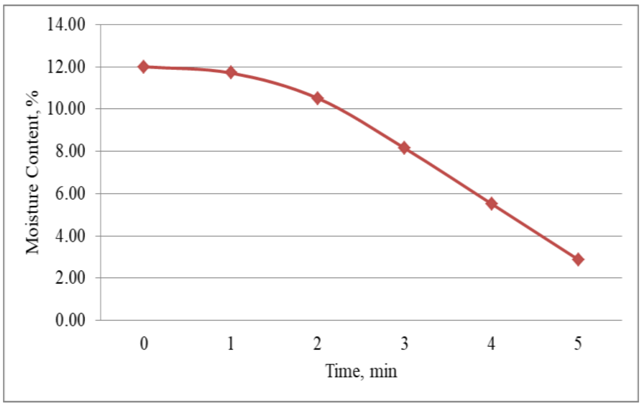

(c)

Fig 2. Drying curve of stingless bee pollens subjected to a) 119W, b) 336W and c) 700W microwave power outputs

At 119W, there was an increase in moisture loss during the first 3 hours of drying and constant weight loss thereafter. In 336W and 700W microwave application, moisture losses at initial stage were slow and start to build up upon completion of drying.

Comparison among means of the moisture reduction rate as affected by microwave power output revealed that there was a significant difference in the drying rates of all treatments. The 700W treatment have significantly higher reduction rate of

Table II. Characteristics of stingless bee pollens dried at different microwave power output

Power Levels	Moisture Content, %	Water Activity	pH	Protein Content, g/100g	Vitamin E Content, mg/100g	Beta Carotene Content, mg/100g
119W	3.95	0.342	3.84	16.2	0.95	0.192
36W	3.93	0.333	3.86	16.3	1.7	0.174
700W	2.96	0.364	3.89	16.1	2.8	0.226

108.42%/hr compared to the other treatments. Lowest average drying rate was observed from 119W with a value of 0.42%/hr. At 336W, moisture reduction rate was 33.04%/hr.

The reason for the decrease of moisture of the stingless bee pollens was due to the higher water molecules content of the samples during the start of the drying that results to a higher absorption of microwave energy. This high absorption of energy leads to higher moisture loss due to moisture diffusion. Continuous moisture loss after the initial stage of drying causes less absorption of microwave energy of the product. This results to the decrease in the drying rate. This phenomenon was due to the generation of heat inside the sample creating a large vapor pressure difference with its surface as a result of volumetric heating [11].

3) Percentage Recovery Output

Table I shows the mean percentage recoveries as affected by the variation of microwave power output after the drying procedure.

Comparison among means revealed that percentage recovery at 119W (91.62%) and 336W (91.60%) were both significantly higher than 700W with a recovery of 90.69%.

The larger mean value of the 700W treatment was due to the high and continuous microwave power output during drying that causes rapid water loss of the bee pollens compared to the other treatments. Because the bee pollens were composed of water, excessive moisture loss contributes to the loss of the weight of the product decreasing the recovery after drying.

B. Characteristics of Fresh and Microwave Dried Stingless Bee Pollens

The stingless bee pollens were round to irregular in shape with sizes varying from 3 mm to 10 mm. The freshly extracted pollen has a powdery finish having four distinct colors: orange, yellow, brown and dark brown (Fig. 3).

1) Moisture Content

Stingless bee pollens were larger and slightly stickier as compared to bee pollen collected by European honeybees. The fresh samples were dried in an oven and determined a moisture content of 12.07%. Other stingless bee pollens collected from

Melipona seminigra and *Melipona interrupta* (Amazonian stingless bees) showed higher moisture content compared to the current study with 53.39% and 37.12%, respectively [12].

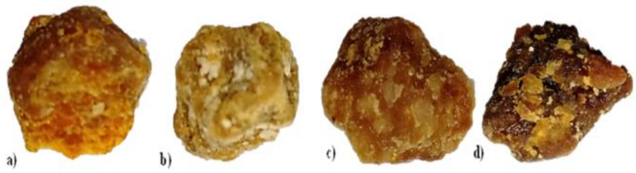

Fig 3. Colors of stingless bee pollens: (a) orange; (b) yellow; (c) brown, and (d) dark brown

The effect of varying microwave power output to the moisture content of stingless bee pollens was shown in Table II.

Comparison among means of the moisture content as affected by microwave power levels revealed that there was no significant difference in moisture between 336W and 119W treatments.

At 119W and 336W the final moisture content recorded were 3.95% and 3.93%, respectively. But because microwave drying has fast water removal ability, higher microwave power output tends to dry the product below 4% even at 1 minute interval. This is true in the case of 700W which has a final moisture content of 2.96% after 5 minutes of microwave drying. The low moisture content was related with the high moisture reduction rate of the 700W treatment.

2) pH

pH level is the degree of acidity or alkalinity of a substance. Acidic food has a pH value between 0 and 7 while alkaline foods has pH value between 7 and 14 having 7 as neutral in the case of distilled water [14]. The pH value of stingless bee pollens in aqueous solution was found to be acidic at 4.04±0.01 but is within the pH range of 4 to 6 based on the Technical Regulation for bee pollen [12].

The pH levels of the microwave dried stingless bee pollens as influenced by varying microwave output was shown in Table II. The highest mean pH value of 3.89 was observed from the 700W treatment and at 119W and 336W outputs, the pH levels were 3.84 and 3.86, respectively. These levels were lower than a pH value of 5 where most microbes stop growing [13].

3) Water Activity

Water activity is an important factor for the preservation of dried commodities. Depending on the level of water activity, microbial growth are prevented which can lead to the spoilage of the product. Therefore maintaining or lowering the water activity should be reduced to minimum.

Water activity (Aw) of fresh bee pollens was tested with a value of 0.622 at 25°C. At this level, no bacterial proliferation can occur but still prone to molds and yeast growth. This is true as bee may sometimes collect fungal spores from moldy plants [14].

These microorganisms were the common cause of spoilage in bee pollens when exposed to the elements. The types of mold and yeast that can thrive in the bee pollens include *Monascus bisporus* and *Saccharomyces rouxii*, respectively [13].

Values recorded after each microwave power output show a reduction of the water activity of microwave dried bee pollens as shown in Table II.

Analysis of variance reveals an insignificant effect of microwave power output to the water activity of the dried stingless bee pollens. Water activities of bee pollen samples were 0.342, 0.333 and 0.364 for 119W, 336W and 700W, respectively. These values were near 0.3 which can prevent enzyme activity, non-enzyme browning and lipid oxidation that can cause deterioration [15].

Data suggest a stable product with no microbial proliferation as all values falls below a water activity of 0.6 which is the growth limit for common microorganisms [13]. Therefore, development of various microorganisms that deteriorate food can be prevented or stopped resulting to food with better shelf life [12].

4) Protein, Vitamin E and Beta Carotene Content

The chemical composition of bee pollens depends on various factors such as floral source, location, climate, soil, species and activity of bees. This can lead to better quality bee pollens compared to others [1][14][15][16].

The protein content of fresh stingless bee pollens was tested and found to be 16.7% w/w. Bee pollens generally has high protein content but the species considered in the study shows a lower protein concentration. However, this value was still within the common range of 10 to 40% w/w [1] and above 8% w/w set by the Technical Regulation for Identity and Quality of Bee Pollen in Brazil [12]

On the other hand, the vitamin E and beta carotene content of stingless bee pollens were 1.1 and 0.118 mg in 100 grams

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which were below the common value of Tocopherol (E) and Beta carotene in most bee pollens literature. Shown in Table III were the quality parameters of fresh stingless bee pollens.

Table III. Properties of fresh stingless bee pollens

Description	Content
Moisture content, %	12.07
pH	4.04
Water Activity (at 25°C)	0.622
Protein, g/100g	16.7
Vitamin E, mg/100g	1.1
Beta carotene, mg/100g	0.118

Microwave dried stingless bee pollens were submitted for protein, vitamin E and beta carotene analysis and the results were presented in Table II.

Composite sampling was done with 336W treatment having the highest protein value of 16.3 g/100 g. At 119W and 336W, protein levels were 16.2 and 16.1 g/100g, respectively. Comparing with the fresh samples, a reduction of 0.4 g was found in the 336W treatment while 0.5 and 0.6 g reduction in the 119W and 700W, respectively.

This shows that microwave energy has a reducing effect on the protein content of stingless bee pollens. This is similar with a report that exposure to microwave energy can cause protein degradation due to the reduction of amino acids in bee pollens collected by *Apis mellifera* [17].

In terms of Vitamin E, a power output of 119W shows a reduction of 0.15 mg/100 g in the vitamin E content of dried bee pollens from 1.1 mg/100 g of the fresh sample to 0.95 mg/100 g. On the other hand, an increase in the vitamin E content of 0.6 and 1.7 mg/100 g was observed at higher power outputs of 336W and 700W, respectively. At 336W treatment, vitamin E content was 1.7 mg/100 g while at 700W, vitamin E value as 2.8 mg/100 g.

The increase of vitamin E may be influenced by the increase of the temperature of the material as higher microwave energy was applied. Higher temperature can disorganized the physical structure of stingless bee pollens causing a rise in diffusion rate that result to higher vitamin E yield [18].

Beta carotene is a provitamin that is a substance needed or can be converted into vitamins. Carotenes are sensitive to light and oxygen but stable even at high temperatures. Drying of products with carotene can concentrate its antioxidants content and preserve carotenoids [15].

119W, 336W and 700W showed an increase of 0.074, 0.056 and 0.108 mg/ 100 g, respectively, in the beta carotene levels of the dried pollens as compared to the fresh sample having 0.118 mg/100g beta carotene. The highest beta carotene yield was recorded from the 700W treatment with 0.226 mg/100g beta carotene followed by 119W and 336W with 0.192 mg/100g and 0.174 mg/100g, respectively.

The increase in the beta carotene content might be because of the breakdown of the carotenoid crystals and the pectin in the cell walls during the application of microwave energy which enhances the availability of carotenoids [19].

C. Determination of Required Microwave Power Output for the Microwaving of Stingless Bee Pollens

Shown in Table 4 was the percent value that 100 g stingless bee pollens have to the average RENI for Filipinos age 16 years old and above [20].

Based on the table above, it was evident that the 700W treatment has the highest value that supports around 56.3% of the RENI of Filipinos for protein, vitamin E and vitamin A.

Table IV. Percent value of the fresh and dried stingless bee pollens to the RENI

	Fresh	119W	336W	700W
Protein, %	26.7	25.9	26.1	25.8
Vitamin E, %	9.2	7.9	14.2	23.3
Vitamin A, %	3.7	6.1	5.5	7.2
Total, %	39.6	39.9	45.8	56.3

CONCLUSION

Based on the results of the study, the following conclusions were made: the microwave oven can be modified for drying purposes using locally available materials; microwave drying of stingless bee pollens using 700W microwave power output has better drying performance compared to 119W and 336W microwave power output; and, microwave drying of stingless bee pollens using 700W microwave power output increases heat stable vitamins like vitamin E and beta carotene but reduces heat sensitive nutrient like protein with increase in drying time.

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