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Microwave and Infrared Heat Processing of Honey and Its Quality

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Application of microwave and infrared radiation was explored for thermal processing of honey and its effect on the physico-chemical characteristics as well as the microbiological quality of honey were studied. Microwave heating provided a rapid means of achieving the desired level of yeast reduction with reduced thermal damage. Though different combinations of heating duration and microwave power intensity achieved the commercially acceptable level of yeast reduction in honey, heating for a shorter duration (15 s) at higher power intensity (16 W/g) was desirable in terms of lower hydroxymethylfurfural (HMF) value (3.8 mg/kg) and higher diastase activity (12.0). Infrared heating was not as rapid as microwave heating but achieved the desired results in a relatively shorter period (3–4 min) offering advantages over the conventional method.

Keywords: diastase activity, honey, hydroxymethyfurfural (HMF), infrared heating, microwave heating, moisture reduction, yeast

Honey, a natural biological product evolved from nectar and of great benefit to human beings both as medicine and food, is consumed in every country of the world in some form. In India about 10,000 metric tons of honey is produced in apiaries and 2–3 times this quantity is produced in forests by rock bees (Wakhle & Chaudhary, 1993). Honey contains glucose, fructose and water, in addition to small quantities of proteins, minerals, organic acids, and vitamins. It is used in food products because of its characteristic flavor, sweetness and texture. The established uses of honey are in baking, confectionery, preserves, spreads and syrups, cosmetics etc (Wilson & Crane, 1975).

The major problem faced by honey producers in tropical countries is its rapid deterioration in quality due to fermentation (Ghazali *et al*., 1994). The unprocessed honey tends to ferment within a few days of storage at ambient temperature because of its high moisture content and yeast count. To prevent fermentation, honey is heat processed before storage. Two important stages of this processing are filtration and heating. Heat processing of honey eliminates the microorganisms responsible for spoilage and reduces the moisture content to a level that retards the fermentation process. Studies have shown that heating honey at 63, 65 and 68°C for 35, 25 and 7.5 min, respectively can destroy the yeast cells completely (Wakhle *et al*., 1996). The conventional process involves indirect heating of filtered honey at 60–65°C for 25–30 min in a tubular heat exchanger followed by rapid cooling in order to protect its natural color, flavor, enzyme content and other biological substances (Wakhle & Phadke, 1995). However, uncontrolled heating results in a deterioration of the quality of the honey and parameters such as diastase activity and hydroxymethylfurfural (HMF) content are altered unfavorably.

Microwave and infrared heating are gaining popularity over conventional heating owing to their inherent advantage of rapidity. The application of microwave heating is well known in the food industry, particularly for tempering, blanching, drying and pasteurization of food material (Ghazali *et al*., 1994). Stearns and Vasavada (1986) studied the effect of microwave processing on the quality of milk and its shelf life. Knutson *et al*. (1988) reported the use of the microwave oven to pasteurize milk, and a continuous laboratory scale system has been successfully developed for this purpose (Kudra *et al*., 1991). Microwave heating is greatly affected by the presence of water in foods (Tulasidas *et al*., 1995) as water is the major absorber of microwave energy in food, consequently, the higher the moisture content, the better are the resultant heating effects. In contrast to conventional heating, microwaves penetrate the material, interact with it and generate heat leading to its rapid heating. Materials containing polar molecules such as water are rapidly heated when exposed to microwave radiation due to molecular friction generated by dipolar rotation in the presence of an alternating electric field. It is also reported that dissolved sugars are the main microwave susceptors in high carbohydrate foods and syrups (Tulasidas *et al*., 1995). Since honey contains a substantial amount of water (18–24%) as well as large amounts of dissolved sugars (70–80%), microwave radiation could be effectively used for heating honey.

Infrared heating of food is also gaining popularity because of the simplicity of construction and operation, its transient response, significant energy savings over other thermal processes and ease of construction of hybrid systems with convective and conductive heating sources (Sandhu, 1986). Infrared dryers provide high rates of energy input to the material surface and the radiant heat flux penetrates the material to a depth, which depends on the nature of the material and the wavelength of the incident radiation (Zbicinski *et al*., 1992). Sugar and water are the two major constituents of honey and both have good absorption bands in the thermal radiation region (Sandhu, 1986). The

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above factors may be successfully utilized for heating honey, which could result in a more efficient process.

In the present work, application of microwave and infrared radiation on thermal processing of honey are explored and their effect on the physico-chemical characteristics and microbiological quality of honey are studied.

Materials and Methods

Material Forest/Rock bee honey extracted from *Apis dorsata* hives was used in the experiments. The raw honey was strained through muslin cloth to remove any suspended particles like pollen, wax, dirt and dust. The strained honey was heated to 40°C and filtered through a leaf filter using polypropylene mesh (80 μm). The filtered honey was stored at 4°C and samples were drawn as and when required. The samples were allowed to reach ambient temperature before heat processing. For all the experimental runs 50 g of filtered honey samples were taken in a 250 ml glass beaker (6.5 cm diameter and 9.5 cm height). The thickness of the honey layer was ~15 mm in the beaker. All the experimental runs were carried out in duplicate, and mean values and standard deviations are reported.

Microwave heating of honey Microwave heating studies were conducted in a micro-convective oven with turntable attachment (Model 900T, 2450 MHz, maximum power of 850 W; BPL-Sanyo, India). Experiments were carried out at different power levels (PL) ranging from 10 to 100 (175–850 W) and for different heating periods of 15 to 90 s. The corresponding microwave input power intensities are expressed in terms of W/g (3.5, 6.3, 9.1, 11.9 and 16.0 W/g corresponding to 10, 30, 50, 70 and 100 PL respectively). The samples were mixed intermittently (once every 15 s) for 2 s for uniform heating. The product temperature was measured at the end of the heating period and reported as peak temperature. The samples were cooled with tap water to room temperature immediately after the heat treatment to prevent quality deterioration. For all the experimental runs, the position of the glass beaker was fixed at the center of the turntable to ensure a consistent heating condition.

Infrared heating of honey A near infrared (NIR) batch oven fitted with infrared lamps (1.0 kW, peak wavelength 1.1–1.2 μm) fabricated at the authors institute was used. To ensure uniform power intensity of 0.2 W/cm^2, the position of the glass beaker and the distance between the source and sample were fixed for all the experimental runs. The samples were heated for a known period (2, 3, 4, 5 and 8 min) and were mixed intermittently (once every 30 s) for 2 s inside the oven for uniform heating. The temperature attained by the sample at the end of the heating period was recorded and reported as peak temperature. The samples were cooled with tap water to room temperature immediately after the heat treatment.

Analyses Moisture content, diastase activity, HMF and yeast count were determined for all the samples. Filtered honey was used as a control.

A hand refractometer (Bellingham Stanley, UK) was used to measure the moisture content. Measurement was made based on the method recommended in the European Regional Standard for honey (CAC/RS 12, 1969). Brix values were converted into refractive indices using AOAC (1980) table. Refractive indices obtained were then converted into percentage moisture content using the Wedmore (1955) table. All calculations were made after applying temperature corrections at 20°C.

The diastase number (DN) was measured based on the method recommended in the European Regional Standard for honey (CAC/RS 12, 1969). The DN is equivalent to Gothe-scale number, that is, ml of 1% starch solution hydrolyzed by the enzyme in 1 g of honey in 1 h at 40°C.

The HMF content was measured based on the method recommended in the European Regional Standard for honey (CAC/RS 12, 1969) and expressed as milligrams per kilogram (mg/kg) of

Table 1. Heating of honey at different power levels of microwave heating.

S. No.	Power level	Power intensity (W/g)	Duration (s)	Peak temperature (°C)	Moisture (%)	Yeast count (cfu/ml) (×10^3)	HMF (mg/kg)	Diastase number
Control				20	21.8	7.00	2.0	16.6
1	10	3.5	15	28	21.8	2.90	2.6	15.8
2	10	3.5	30	32	21.8	1.50	3.0	15.2
3	10	3.5	45	40	21.2	0.80	3.6	14.2
4	10	3.5	60	51	21.2	0.50	4.2	13.6
5	10	3.5	90	66	20.8	0.30	4.7	12.5
6	30	6.3	15	36	21.8	2.30	2.8	14.8
7	30	6.3	30	45	21.2	0.80	3.4	13.4
8	30	6.3	45	62	20.8	0.50	4.2	11.3
9	30	6.3	60	73	20.8	0.40	4.5	10.3
10	30	6.3	90	106	20.2	0.20	4.9	9.0
11	50	9.1	15	45	21.2	2.10	3.4	13.1
12	50	9.1	30	56	21.2	0.60	3.9	11.9
13	50	9.1	45	84	20.8	0.40	4.4	10.0
14	50	9.1	60	96	19.8	0.20	4.7	8.6
15	50	9.1	90	106	19.8	0.15	5.5	8.0
16	70	11.9	15	50	21.2	1.60	3.6	12.3
17	70	11.9	30	66	20.8	0.50	4.2	10.8
18	70	11.9	45	96	20.2	0.30	4.8	9.0
19	70	11.9	60	101	19.8	0.20	5.3	8.0
20	100	16.0	15	54	21.2	0.45	3.8	12.0
21	100	16.0	30	89	20.8	0.25	4.6	9.4
22	100	16.0	45	105	19.8	0.15	5.4	8.1
23	100	16.0	60	110	19.2	0.10	7.2	7.0

Standard deviation (SD) range for peak temperature, moisture, yeast count, HMF and diastase number measurements were 1.0–2.0, 0.30–0.60, 8–65, 0.1–0.2 and 0.1–0.3, respectively.

honey.

The yeast count was estimated using a pour plate technique. Plates with potato dextrose agar medium (pH 5–6) were incubated with honey samples after suitable dilution with sterilized water (1 : 9). Microbial colonies were counted after incubation at 30°C for 24 h and expressed as colony forming units/ml (cfu/ml).

Results and Discussion

Microwave heating Moisture content, yeast count, HMF, diastase value of microwave heated samples and the peak temperature attained by the sample during heating are given in Table 1. The extent of change in properties mainly depended on the power level (power intensity) and duration of heating. Changes were prominent in samples that were heated at higher power levels and for longer durations. The peak temperature attained by the sample depended on the power level used as well as duration of heating.

Honey is contaminated with yeast, as it is a product obtained from the natural environment. Lockhead (1933) had reported that a raw honey sample containing more than 20% moisture readily undergoes fermentation irrespective of the yeast count. However, the processed honey containing yeast cells could be safely stored at room temperature provided the count is apparently insufficient to initiate fermentation. Ghazali *et al.* (1994) reported that processed honey with a yeast count of 8.00×10^2 cfu/ml (20.8% moisture) could be stored at 28±2°C for 16 weeks without fermentation. In the present study, reduction in yeast count to the extent of the commercially acceptable level ($<5.0\times10^2$ cfu/ml) reported by the earlier researchers (Ghazali *et al.*, 1994) was observed at power levels of 10, 30 and 50 when the samples were heated for more than 30–45 s. At higher power levels of 70 and 100, heating duration of 30 and 15 s, respectively, was sufficient to lower the yeast count below 500 cfu/ml. A plot of the reduction of yeast count with time at different power levels is shown in Fig. 1. The reduction in yeast count was rapid, generally during the first 30 s, and the rate of yeast reduction was directly related to the input power intensity. The reduction of yeast count is attributed to the rapid increase in sample temperature due to microwave exposure, leading to rupture of yeast cell walls present in the sample.

Excessive amount of HMF has been considered evidence of overheating, implying a darkening of color and a loss of freshness of honey. The increase in HMF value was marginal at lower heating duration and rapidly increased in the samples heated for a longer duration at higher power levels of 70 and 100. However, these values were far below the maximum permissible statutory level of 40 mg/kg of honey (European Regional Standard for honey, 1969). The trends in the variation of HMF values of the samples clearly depicted the sensitivity of honey to the period of heating and temperature (power level). Variation of HMF with duration of heating at different power levels is shown in Fig. 2.

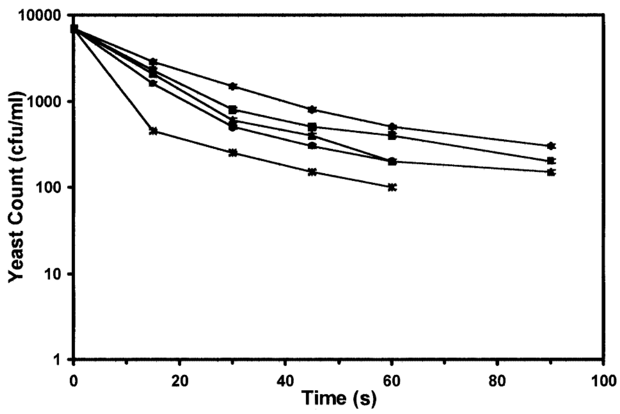

Fig. 1. Reduction in yeast count with duration of heating at different power levels (PL) of microwave heating. ◆, PL 10; ■, PL30; ▲, PL50; ●, PL70; *, PL100.

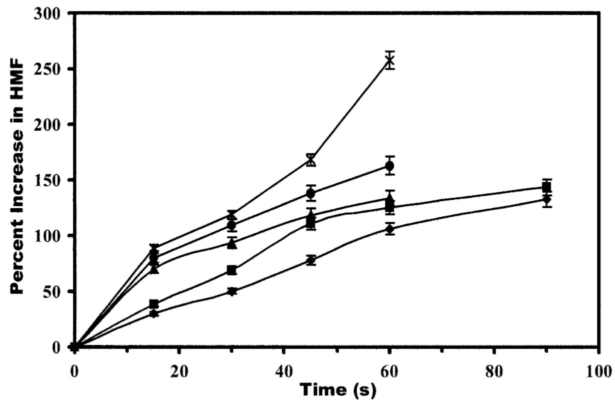

Fig. 2. Reduction in HMF with duration of heating at different power levels (PL) of microwave heating. ◆, PL 10; ■, PL30; ▲, PL50; ●, PL70; *, PL100.

Honey contains many enzymes, the major ones being invertase, amylase and glucose oxidase (White, 1975). The determination of enzyme diastase in honey has long been used to detect the overheating of honey (Kervliet & Putten, 1973) and the European Regional Standard for honey (1969) specifies the minimum value for diastase activity in processed honey (8.0). The enzyme content in honey is measured as diastase activity and expressed as diastase value. Heating affects the enzyme activity and the diastase activity showed a decline with heating under all conditions employed. The reduction in diastase value with heating duration at different power levels is depicted in Fig. 3. It was observed that long heating periods of 60 to 90 s duration at power levels of 30, 50 and 70 reduced the diastase activity of honey by nearly 50% of its original value. At a power level of 100, heating above 45 s resulted in reduction of the diastase value to a level lower than the minimum permissible statutory value of 8 (European Regional Standard for honey, 1969).

Reduction in moisture content was above 9% at power levels of 50, 70 and 100 when the samples were heated for 60 s. Figure 4 indicates the reduction in moisture content with heating duration at different power levels. Larger reduction in moisture content was not observed at lower power levels. Similar observations were also made by Ghazali *et al.* (1994). The final moisture content in most of the samples was in the range of 19.8 to 21.2%, which is below the acceptable level (22%) for commercially processed honey.

Though different combinations of time and microwave power level could be used to achieve the commercially acceptable level of yeast reduction in honey, it is equally important to take peak temperature attained by the sample into consideration. Heating of honey above 90°C results in caramelization of sugar (Yener *et*

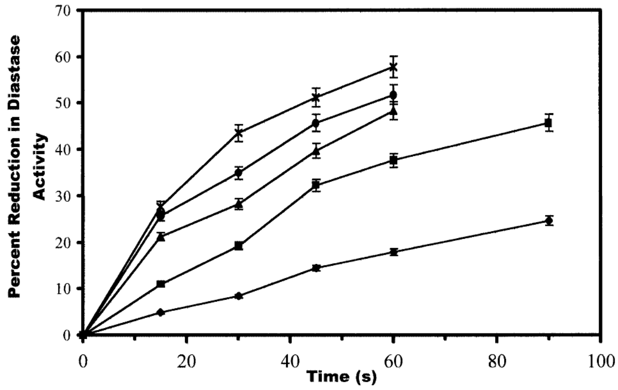

Fig. 3. Reduction in diastase value with duration of heating at different power levels (PL) of microwave heating. ◆, PL 10; ■, PL30; ▲, PL50; ●, PL70; *, PL100.

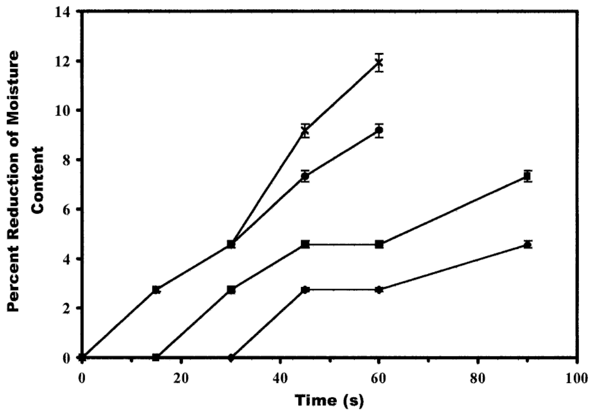

Fig. 4. Reduction in moisture content with duration of heating at different power levels (PL) of microwave heating. ◆, PL 10; ■, PL30; ●, PL70; *, PL100.

al., 1987). Also, it seems that this has a direct bearing on the increase in HMF value and loss in diastase activity. From Table 1 it can be inferred that when the peak temperature exceeded 85°C, the diastase number fell below 10 and, in general, HMF value increased beyond 4.4 in these samples. Therefore, it is beneficial to achieve the desired yeast reduction by choosing any suitable combination of power level and duration that will maintain the temperature of honey well below 85–90°C. Among the various selected combinations, higher power level and shorter duration seems to be better than lower power level and longer duration. At power level 100 (power intensity 16 W/g), heating for 15 s resulted in substantial reduction in yeast count (450 cfu/ml), lower HMF value (3.8 mg/kg) and higher diastase activity (12.0). Also, the desired changes in the sample were achieved at a much lower processing temperature (54°C).

Infrared heating In infrared heating experiments, the samples were heated continuously for 2, 3, 4, 5 and 8 min and results are presented in Table 2. In all the cases, heating caused substantial reduction in yeast count. Heating for 5 min resulted in a product temperature of 85°C, HMF increase of 220% and 37% drop in enzyme activity. When the samples were heated for 8 min no viable colony forming units of yeast were noticed. However, the diastase activity fell drastically in these samples and only minute traces of activity were noticed, clearly indicating excessive heating of honey that also showed up in a very high product temperature (110°C). A heating period of 3 to 4 min was adequate to obtain a commercially acceptable product, which met all the statutory requirements of quality.

Table 2. Continuous heating of honey with infrared radiation.

S. No.	Time (min)	Temperature (°C)	Moisture (%)	Yeast count (cfu/ml)	HMF (mg/kg)	Diastase number
Control			21.8	7000	2.0	16.6
1	2	47	20.2	500	3.2	13.8
2	3	61	19.8	300	3.6	12.4
3	4	74	19.8	200	4.6	11.6
4	5	85	19.2	150	6.5	10.5
5	8	110	18.2	Nil	7.9	Traces

Standard deviation (SD) range for peak temperature, moisture, yeast count, HMF and diastase number measurements were 1.0–2.0, 0.2–0.5, 20–40, 0.1–0.3 and 0.1–0.2, respectively.

Conclusion

Different combinations of heat treatment (temperature and duration) can be used to achieve the main objective of yeast reduction in honey to a commercially acceptable level, while it is important to maintain the temperature of the product below 90°C. Microwave heating can be effectively used for thermal processing of honey, as it provides a rapid heating to achieve the desired results for long-term storage. Infrared heating is not as rapid as microwave heating but the desired results are obtained in a relatively shorter period of 3–4 min offering advantages over the conventional method. Further studies are suggested to establish the relationship between various processing conditions and honey quality in continuous flow systems to reach the industrial application level.

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