Development and evaluation of low cost honey heating-cum-filtration system

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Abstract A fully mechanized honey heating-cum-filtration system was designed, developed, fabricated and evaluated for its performance. The system comprised of two sections; the top heating section and the lower filtering section. The developed system was evaluated for its performance at different process conditions (25 kg and 50 kg capacity using processing condition: 50 °C heating temperature and 60 °C heating temperature with 20 and 40 min holding time, respectively) and it was found that the total time required for heating, holding and filtration of honey was 108 and 142 min for 25 kg and 50 kg capacity of machine, respectively, irrespective of the processing conditions. The optimum capacity of the system was found to be 50 kg and it involved an investment of Rs 40,000 for its fabrication. The honey filtered through the developed filtration system was compared with the honey filtered in a high cost honey processing plant and raw honey for its microbial and biochemical (reducing sugars (%), moisture, acidity and pH) quality attributes. It was observed that the process of filtering through the developed unit resulted in reduction of microbes. The microbiological quality of honey filtered through the developed filtration system was better than that of raw honey and commercially processed honey. The treatment conditions found best in context of microbiological counts were 60 °C temperature for 20 min. There was 1.97 fold reductions in the plate count and 2.14 reductions in the fungal count of honey processed through the developed filtration system as compared to the raw honey. No coli-forms were found in the processed honey. Honey processed through developed unit witnessed less moisture content,

acidity and more reducing sugars as compared to raw honey, whereas its quality was comparable to the commercially processed honey.

Keywords Biochemical quality · Filtration · Heating · Honey · Microbiological quality

Introduction

Honey has been recognized as a sweet food for human beings, especially for infants since ancient times (Shamla and Jyothi 1999). It is delicious and nutritious and has high medicinal value in comparison to other sweeteners. The consumption as well as demand of honey is rising throughout the world market. To meet the demand of the market, many people have adopted bee keeping as one of their vocations. A considerable increase in the number of bee keepers has been observed in Punjab, which has resulted in a golden revolution in the state in respect of honey production.

Bee farming has been on increase during the last 2 decades and its importance has been realized at national level. Bee farming has emerged as an important agro-based industry in the state. A number of bee keeping equipment manufacturers have emerged and they are using their own design, fabricating and marketing bee keeping equipments. The techniques/tools employed at present are of primitive and crude in nature, resulting in low efficiency of extraction as well as low quality of honey, sometimes in unhygienic conditions. Since bee keeping itself has been started on scientific lines, there is a need to improve design, fabricate and evaluate various honey production and processing equipments/systems for achieving better quality of honey. Several researchers have contributed to the development of different honey processing equipments (Owens

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1964; Detroy and Owens 1967; Strickland 1982; Berry 1994; Wakhle and Padhke 1995; Sehgal et al. 2004)

In the honey production and processing system, the apiary honey collected in the irrigated agricultural plains is usually thin. Beekeepers usually extract honey from comb that contains some immature honey. Honey does not contain any harmful ingredients, so equipments needed for the processing and methods are easy and simple. However, the raw honey could not be directly consumed and thus processing is required which include heating, filtration and bottling. The raw honey is processed to retard granulation and inactivate or kill yeast cells that cause fermentation. The normally thick mellifera honey needs processing, that includes light heating to bring down its viscosity for straining and bottling. At the producers level, heating of honey is usually done by keeping the container with honey in a large vessel with water and heating the water thus resulting in an indirect heating. It is stirred by dry sticks. There is no control on the temperature to which honey is heated. Thus, to overcome these shortcomings the present study was undertaken to design, develop and evaluate a fully mechanized low cost honey heating-cum-filtration system.

Materials and methods

Description of machine The honey heating cum filtration system was designed for an optimum capacity of 50 kg/batch (Fig. 1). The system has two sections; the top heating section and the lower filtering section. The heating section consists of a double walled cylinder and two electric heating elements, each of 2 kW fixed in the space in between the outer GI cylinder (ϕ 521 mm) and inner SS cylinder (ϕ 368 mm) filled with water which is heated by heating element provided therein. In addition a separate pipe is provided for filling/unfilling of water in/from the system which is attached with a tulli pump for recirculating the water causing turbulence. This helps in maintaining uniform temperature of water used for indirect heating of honey. In order to have uniform temperature profile throughout the heated honey, an electrically operated six fins stirrer was attached which is operated by 0.25 hp motor, stirring the sample at optimum speed of 421 rpm as and when required. The heated honey is passed to the filtration unit through the hole (ϕ 38 mm) provided at the bottom of the inner cylinder and extended through a pipe having gate-valve. The filtration section consists of a stainless steel cylinder having lid of four layered muslin cloth. The operator was comfortable while working with it. One person is required for its operation. The initial investment incurred in fabrication of honey heating-cum-filtration system was Rs.40, 000/-.

Evaluation of machine The developed machine was evaluated for its operational time for different capacities, time-

temperature combinations. The honey heated at different time-temperature combinations and filtered through developed system were compared for its quality (biochemical and microbiological) with raw honey as well as with the honey processed through high cost honey processing plant. Each experiment was replicated thrice. The operational data were statistically analyzed using Factorial experiment in Completely Randomized Design by using computer software package (Cheema and Singh 1990). The critical difference (CD) was calculated at 5 % level of significance.

Microbiological quality Standard methods for microbiological analysis were adopted for honey (Anon, 1982). Microbiological quality evaluation of honey samples was done by serial dilution agar plate method or viable count method. Pour plates of plate count agar were prepared for aerobic plate count and total fungi (yeasts and moulds) were enumerated by Potato Dextrose Agar. Coliforms were observed using MacConkey agar medium. Each experiment was replicated thrice. The microbiological data were statistically analyzed using experiment in Completely Randomized Design by using computer software package (Cheema and Singh 1990). The critical difference (CD) was calculated at 5 % level of significance.

Bio-chemical quality Moisture content of honey was calculated as per BIS (IS 4941: 1994) standards. Acidity of the honey was estimated by the procedure of AOAC (2000) and expressed in terms of formic acid. The pH of the honey was determined with a digital pH meter. Total reducing sugars was estimated according to the method suggested by Nelson (1944). Hydroxy methyl furfural (HMF) content was measured by carrying out Fiehe's test. Appearance of yellow colour indicated a negative reaction and cherry red colour indicated positive reaction. Each experiment was replicated thrice. The biochemical data were statistically analyzed using experiment in Completely Randomized Design by using computer software package (Cheema and Singh 1990). The critical difference (CD) was calculated at 5 % level of significance.

Results and discussion

Performance of developed Honey heating cum filtration system The developed fully automated prototype of honey heating cum filtration system was evaluated in the laboratory for its performance at different process conditions (25 kg and 50 kg capacity with processing conditions of 60 °C heating temperature with 20 min holding time and 50 °C heating temperature with 40 min holding time) and found its optimum capacity to be 50 kg of raw honey with average total operational time (heating, holding & filtration)

Fig. 1 Schematic view of low cost honey heating-cum-filtration system

Table 1 Operational responses of developed honey heating cum filtration system

Operational Parameters			Responses		
Capacity (kg)	Temp of Honey (°C)	Holding time (min)	Time required to reach the desired temp (min)	Filtration time (min)	Total time (min)
25	50	40	62.0±1.15	13.3±0.67	115.3±1.76
25	60	20	69.3±0.67	10.7±0.88	100.0±1.52
25	50	20	63.3±1.05	14.8±0.95	98.0±1.00
25	60	40	70.5±1.00	9.8±0.98	120.4±1.90
50	50	40	86.6±0.88	21.3±0.67	148.0±1.00
50	60	20	98.6±0.88	18.3±0.88	137.0±1.15
50	50	20	88.5±0.74	19.2±0.68	127.8±1.40
50	60	40	97.1±1.05	20.3±0.88	154.4±1.90

Values are mean ± S.E of N=3 replications

requirement of approximately 108 and 142 min for 25 kg and 50 kg capacity of machine, respectively, irrespective of the processing conditions. The time required to reach the desired temperature varied from 62 to 98 min; filtration time from 9.87 to 21.33 min and total operation time from 98 to 154 min (Table 1). It is clear from Table 2 that the processing time for reaching to the desired temperature was significantly affected by the capacity of machine, processing temperature whereas, holding time and all interactions showed insignificant affect at 5 % level of significance. The filtration was significantly affected by the capacity, processing temperature and holding time showing increase in filtration time with increase in capacity while decrease with increase in processing temperature. The total operational time was also significantly affected by all the three selected operational parameters showing significantly higher values with increase in capacity of machine as well as processing holding time (Table 2).

Developed system and bio-chemical quality of honey The honey processed through new modified honey unit was

compared with raw honey as well as commercially processed honey for its biochemical (reducing sugars (%), moisture, acidity %, pH and HMF) quality attributes.

Moisture content Processing of honey at both the selected temperatures resulted in slightly lower moisture content than raw honey thus indicating that heating resulted in slight reduction in moisture content. However, no significant difference in moisture content was found between honey processed at different temperatures for both the selected holding time i.e. 20 and 40 min (Table 3). Moisture content of processed honey was also comparable to commercially processed honey. Maximum limit is 20 % as recommended by Agmark of India (Alam 2010).

Acidity and pH Irrespective of the processing temperature and processing time, the acidity (per cent formic acid) in the processed honey was found to be significantly less than the raw honey. Acidity of raw honey was 0.187 as compared to 0.13 for honey processed at 60 °C for both the selected holding time and 0.142& 0.144 for honey processed at 50 °C for

Table 2 Effect of operational parameters on selected responses

Responses	Operational Capacity of m/c; A		Parameters Temp of Honey; B		Holding time; C	
	25 kg	50 kg	50 °C	60 °C	20 min	40 min
Time required to reach the desired temp (min)	65.9	92.1	74.2	83.8	79.0	79.0
CD (0.05)	1.367		1.367		NS	
	AB: 1.93	AC: NS		BC: NS	ABC: NS	
Filtration time (min)	12.3	19.6	18.0	13.9	16.6	15.3
CD (0.05)	0.983		0.983		0.983	
	AB: NS	AC: NS		BC: NS	ABC: NS	
Total time (min)	108.2	141.7	122.2	127.7	115.6	134.3
CD (0.05)	1.79		1.79		1.79	
	AB: 2.53	AC: NS		BC: NS	ABC: NS	

Values are the factor means; AB, AC, BC, ABC represents the interaction of different operational parameters

Table 3 Bio chemical attributes of selected honey

Source of honey	Moisture content	pH	Titration acidity	Reducing Sugars
Raw honey	19.3±0.31	3.2±0.05	0.187 ^c ±0.003	66.1 ^a ±0.75
H1	18.4±0.29	3.4±0.03	0.142 ^{a b} ±0.004	74.2 ^c ±0.92
H2	18.4±0.28	3.4±0.04	0.144 ^b ±0.002	74.4 ^c ±0.64
H3	18.4±0.24	3.3±0.03	0.130 ^a ±0.004	72.7 ^{b c} ±0.65
H4	18.4±0.30	3.3±0.04	0.130 ^a ±0.004	72.0 ^b ±0.92
Commercial honey	18.5±0.26	3.3±0.06	0.144 ^b ±0.005	72.3 ^b ±0.64
CD (0.05)	NS	NS	.013	1.875

Values are mean ± S.E of *N*=3 replications; Same superscript within column represents non-significant difference and different superscript within column represents significant difference

Processed honey from developed system H1 (50°C, 20 min), H2 (50°C, 40 min), H3 (60°C, 20 min) and H4 (60°C, 40 min)

20 min and 40 min respectively (Table 3). The difference in pH of processed, commercial and raw honey was found to be statistically non-significant at 5 % level of significance whereas, the pH of processed honey was slightly higher. The raw honey has pH 3.24 whereas processed honey had pH 3.35 at 50 °C for both the selected holding time and 3.32 & 3.31 at 60 °C for 20 min and 40 min respectively (Table 3). Commercially processed honey had acidity 0.144 as which were comparable to honey processed at 50 °C. The honey as recommended by Agmark of India should have the maximum limit of 0.20 % acidity (Alam 2010).

Reducing sugars and HMF A significant difference in reducing sugar content was found between processed honey and raw honey. Honey processed through developed system possessed highest content of reducing sugars (74.2 % and 74.4 % at 50 °C for 20 and 40 min; 72.7 % and 72.0 % at 60 °C for 20 min and 40 min holding time) followed by commercially processed honey (72.3 %). Lowest content of reducing sugars i.e. 66.1 % was found in raw honey (Table 3). The increase in reducing sugar content of processed honey might be due to removal of impurities during filtration by developed filtration unit. The Agmark standard for reducing sugars is a minimum

of 65 % (Alam 2010). Hydroxy methyl furfural content was not found qualitatively in raw as well as processed honey as Fiehe's test gave negative reaction.

Developed system and microbiological quality of honey Microorganisms in honey influence the quality of honey. Honey has anti-microbial properties that discourage the growth or persistence of many microorganisms (Anon 2000). Since it is very difficult to remove microorganisms from honey, it is more practical to learn how to block their entry. This can be done by following honey house sanitation guidelines and good manufacturing practices. The process of filtering reduces or eliminates many microbes (Snowdon and Cliver 1996).

Honey heated at 60 °C temperature with 20 min holding time and filtered through the developed filtration system exhibited highest microbiological quality, as compared to all other treatments. There is 1.97 fold reduction of plate count and 2.14 fold reductions in the fungal count by filtration as compared to the raw honey. The quality of honey treated at 60 °C for 20 and 40 min is almost comparable, as the difference in the microbial count of honey at both treatments was insignificant. The coli forms, an indicator of unsanitary conditions have not been detected in filtered honey treated at 60 °C (Table 4).

Table 4 Microbiological quality of selected honey

Source of honey	Plate count (cfu/g)	Fungal count (cfu/g)	Coli forms (cfu/g)
Raw honey	368.0 ^a ±0.003	60.0±0.010	1.0±0.006
H1	201.0 ^b ±0.001	48.0±0.005	0.0±0.0
H2	189.0 ^c ±0.003	30.6±0.008	0.0±0.0
H3	187.0 ^c ±0.002	28.3±0.002	0.0±0.0
H4	186.4 ^c ±0.015	28.0±0.005	0.0±0.0
Commercial honey	487.0 ^d ±0.041	125.0±0.013	1.3±0.009
CD (0.05)	3.848	NS	NS

Values are mean ± S.E of *N*=3 replications; Same superscript within column represents non-significant difference and different superscript within column represents significant difference

Processed honey from developed system H1 (50°C, 20 min), H2 (50°C, 40 min), H3 (60°C, 20 min) and H4 (60°C, 40 min)

The difference in the plate count of processed, commercial and raw honey was found to be statistically significant at 5 % level of significance. Highest plate count was exhibited by the commercial honey, followed by raw honey and the least count was observed in processed honey (Table 4). The microbiological quality of raw honey was better than that of commercially processed honey in respect of total plate count and fungi (yeasts and molds), which indicates secondary (after-harvest) contamination. Thus honey filtered through the developed filtration system exhibited higher microbiological quality than raw honey. The holding time of 20 min at 60 °C can be considered as the best treatment. The coli forms, an indicator of unsanitary conditions have not been detected in filtered honey through the developed unit. The honey filtered through the developed filtration system had adequate microbiological quality as they had counts lesser than the standard specified microbiological limits of 10000, 1000 and 100 cfu/g for plate count, fungal count and coli forms respectively (International commission on microbiological specifications for foods 1982).

Conclusions

The developed fully automated prototype of honey heating cum filtration system was evaluated in the laboratory for its performance at different process conditions (25 kg and 50 kg capacity using processing condition: 50 °C heating temperature and 60 °C heating temperature with 20 min and 40 min holding time respectively) and it was found that the total time required for heating, holding and filtration of honey was approximately 108 and 142 min for 25 kg and 50 kg capacity of machine respectively irrespective of the processing conditions. The optimum capacity of the designed unit was 50 kg of raw honey. The microbiological quality of honey filtered through the developed filtration system was best at 60 °C for 20 min. The microbiological quality of honey filtered through the developed filtration system was better than that of raw honey. The honey

processed through the developed unit had less acidity and more reducing sugars as compared to raw honey. Hydroxy methyl furfural content was not found in honey as Fiehe's test gave negative reaction. The biochemical and microbiological quality of filtered honey through the developed unit caters to the international standards set for the honey.

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