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Changes in physico-chemical properties of coffee due to hot air assisted microwave drying

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SUMMARY :
Coffee is one of the most popular beverages in the world. One of the principle technological processes is drying; giving rise to the formation of the characteristic colour, flavour and taste of coffee brew. Conventionally there are two types of drying techniques used in the coffee processing, (sun drying and mechanical drying). The initial moisture content of harvested coffee is about 55-60 per cent and after drying lowers the moisture content to around 12 per cent (w.b). Drying should be uniform to obtain acceptable colour, size along with the removal of pests for a longer safe storage. Since coffee production is seasonal, traditional sun drying is quite tough. In recent years, microwave drying has gained popularity as an alternative drying method for a wide variety of food and agricultural products. With the fixed hot air temperature of 45°C, three different microwave output powers ranging from 0.5 to 1.5 kW and three different belt speed ranging from 5mm/s to 15mm/s were used in the drying experiments. Increasing the microwave output power resulted in a significant decrease in drying time within 5 per cent significance level. While the belt speed had no significant effect on the total drying time but had a significant effect on the physico-chemical properties.

KEY WORDS : Microwave, Coffee, Drying, Physico-chemical properties

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Coffee is one of the most popular beverages in the world. Nearly 25 million farmers in 50 countries around the world depend on coffee for a significant part of their livelihoods (Cague *et al.*, 2009). The genus coffee belongs to the botanical family of Rubiaceae and comprises more than 90 different species (Davis, 2001). The characteristic, rich and pleasant aroma and colour of coffee brews is a result of complex processes leading from green coffee beans to the cup of coffee. One of the principal postharvest processes is drying that gives rise to the formation of the characteristic colour, flavour and taste of coffee brews. In 2010-11 according to U.S. Department of Agriculture 12 million tonnes of green coffee is produced.

Brazil is by far the largest grower and exporter of green coffee beans in the world followed by Vietnam, Colombia, Indonesia, Ethiopia and India – producing nearly 2.5 million tonnes of green coffee beans per year (Franca *et al.*, 2005). Coffee plants are grown in tropical and subtropical regions of Central and South America, Africa, and South East Asia, mainly in regions with temperate and humid climates (Schenker, 2000). Coffee cherries are harvested each year when they are bright-red, glossy and firm. After removing the outer hull, the seeds inside of the cherry are commonly called "green coffee beans". The quality of the green coffee beans is dictated by a number of parameters, including bean size, colour, shape, method of drying, crop year, and presence of defects (crack, withered bean, bean in parchment, mouldy bean, etc.).

India is the seventh largest producer of coffee in the world. It produces both variety of coffee *i.e.* Arabica and Robusta. The bulk production taking place in the southern states and most noted is Monsooned Malabar variety. Indian coffee has created a niche for itself in the international market, particularly Indian Robusta which is highly preferred for its good blending quality. Arabica coffee from India is also well received in the international market. India is perhaps the only coffee producing origin whose coffees are fully shade grown, entirely hand-picked and sun dried.

After harvesting, green coffee beans should be dried to 10-14.5 per cent (w.b) moisture content and stored below 26^{o}C under dry environment (50-75 % RH) to maintain the bean quality and to prevent the growth of mould (Gopalkrishna *et al.*, 1971; Kulaba, 1981 and Betancourt and Frank, 1983). Under optimal storage conditions, green coffee beans may be stored for more than 3 years (Bucheli *et al.*, 1998).

Green coffee processing :

Green coffee is produced either by dry processing or by wet processing. After harvesting, the coffee fruits are separated from the pulp, which is carried out by dry or wet processing (Clarke and Macrae, 1987 and Illy and Viani, 1995). The dry process is simple and inexpensive. The whole cherries are dried under the sun in open air, followed by the separation of the hull (dried pulp and parchment) for getting the green beans. On the contrary, the wet process requires more care and investment, but results in a superior coffee quality. In the wet process, the pulp of the coffee cherries, which is made up of exocarp and mesocarp, is removed mechanically, but the parchment remains attached to the beans. After drying either under the sun or in a dryer, the parchment is removed to produce the green coffee beans. Flow diagram for green coffee processing is given in Fig A.

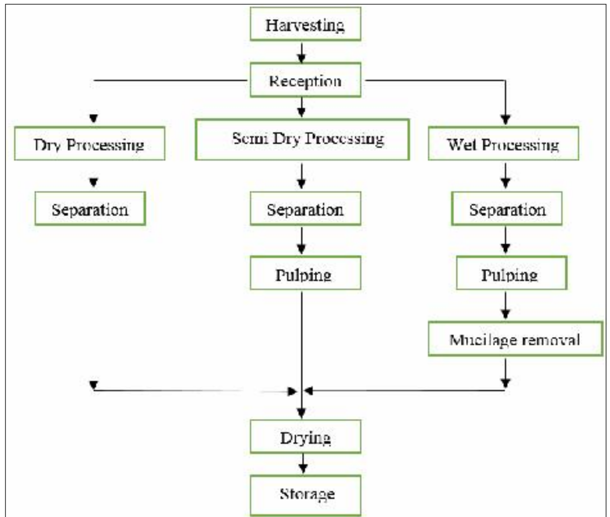

Fig. A : General scheme of coffee processing and preparation of green coffee beans

Chemical composition and nutritional value of coffee:

Green coffee beans are mainly composed, like most plant tissues, by insoluble polysaccharides like cellulose and hemicellulose (50 % w/w). They contain also soluble carbohydrates, such as the monosaccharaides fructose, glucose, galactose and arabinose, the oligosaccharides

Table A : Chemical composition of green Arabica and Robusta coffee beans (g/100g)

Component	Arabica coffee	Robusta coffee
Polysaccharides	49.8	54.4
Sucrose	8.0	4.0
Reducing sugars	0.1	0.4
other sugars	1.0	2.0
Lipids	16.2	10.0
Proteins	9.8	9.5
Amino acids	0.5	0.8
Aliphatic acids	1.1	1.2
Quinic acids	0.4	0.4
Chlorgenic acids	6.5	10.0
Caffeine	1.2	2.2
Trigonelline	1.0	0.7
Minerals (as oxide ash)	4.2	4.4
Volatile aroma	traces	traces
Water	8 to 12	8 to 12

sucrose, raffinose and stachyose and polymers of galactose, mannose, arabinose and glucose. Soluble carbohydrates act binding aroma, stabilizing foam, sedimenting and increasing viscosity of the extract. In addition, non-volatile aliphatic acids (citric, malic and quinic acids) and volatile acids are also present (such as acetic, propanoic, butanoic, isovaleric, hexanoic acids). Oils and waxes are also important constituents, accounting for 8 to 18 per cent of the dry mass, together with proteins and free amino acids (9-12 % w/w) and minerals (3-5% w/w). (Arya and Rao, 2007; Belitz *et al.*, 2009; Clifford and Willson, 1985 and Gonalez-Rios *et al.*, 2007). Table A shows the chemical composition of green Arabica and Robusta beans.

There are many compounds in coffee that are often thought to have implications upon human health.These include caffeine, micronutrients and chlorogenic acid. The coffee beverage is rich in biologically active substances such as nicotinic acid, trigonelline, quinolinic acid, tanninc acid, pyrogolic acid and caffeine (Minamisawa *et al.*, 2004).

Sometimes coffee quality became low due to the hydrolysis of triacylglycerols (the major constituent of coffee lipid) releasing free fatty acids which are oxidized at the time of storage. Multon *et al.* (1973) reported that free amino acids and sugars are degraded while lipids are oxidized and produce off flavour at the end of the storage after drying.

According to Esquivel *et al.* (2010) coffee beneficial have been attributed solely to its most intriguing and investigated ingredient caffeine, but it is now known that other compounds also contribute to the valuable properties of this beverage. However, caffeine has also some negative effects such as sleepless-ness and mild addiction, which has prompted development of a decaffeinated coffee industry (Dufrene and Rubinstein, 2010), which might also benefit from naturally decaffeinated coffee genotypes (Silvarolla *et al.*, 2004). High dose of caffeine also cause anxiety, restlessness, tension, nervousness and psychomotor agitation (Daly and Fredholm, 1998), while long term use of this alkaloid may increase the risk of cardiovascular diseases, with individual differences in caffeine response, probably related to genetic factors (Yang *et al.*, 2010).

Green (or raw) coffee is a major source of CGA in nature (5–12 g/100 g) (Farah *et al.*, 2006). Recent studies demonstrated that the consumption of green coffee extracts produced antihypertensive effect in rats and humans (Suzuki *et al.*, 2002 and Kozuma *et al.*, 2005), improvement in human vasoreactivity (Ochiai *et al.*, 2004), inhibitory effect on fat accumulation and body weight in mice and humans (Shimoda *et al.*, 2006 and Dellalibera *et al.*, 2006) and modulation of glucose metabolism in humans (Blum *et al.*, 2007). Such biological effects have been attributed to CGA present in green coffee. The major CGA in green coffee are 3-, 4-, and 5-caffeoylquinic acids, 3,4-, 3,5- and 4,5-dicaffeoylquinic acids, 3-, 4- and 5-feruloylquinic acids and 3-, 4- and 5-pcoumaroylqunicacids.Caffeoylferuloyl-quinic acids are minor CGA compounds also found in green coffee, especially in *C. canephora* species.

Isamil *et al.* (2012) conducted a study on the changes of physico-chemical properties of coffee beans in 8 month storage period. After the storage, the physical properties of the coffee changed as the coffee beans expanded in size, reduced in mass and density and became brighter in colour. Changes in the chemical properties were also detected where the moisture decreased and the ash content increased. In addition, the sucrose level was found to decrease with a corresponding increase in chlorogenic acid. During storage, the counts of yeast and mould were reduced. The overall conclusion was that the coffee beans reduced in quality during storage.

Drying is important to decrease the moisture content from (45-50) per cent (w.b) to (10-12) per cent (w.b) and for the safe storage of the coffee beans for a long period of time. Researches have reported that the size and the dimension changes as a function of moisture content as size expansion is probably due to moisture absorption. Isamil *et al.* (2012) reported that the moisture content has a significant effect on the brightness of the beans. Brightness increases with the increase in moisture content and *vice versa*.

In another study (Tharappan and Ahmad, 2006) concluded that coffee beans undergoing a monsooning process in India could increase 1.5 times of their original size due to moisture absorption. Isamil *et al.* (2012) showed that in case of Liberica beans moisture contentdecreased but the size of the bean increases at the time of storage period of 8 months. The beans expansion is not because of moisture content but forsome unknown factors.

After drying of parchment coffee from outside there is no such difference in the colour of the coffee sample.

After shelling that is removal of the parchment and the silver skin the colour value changes from yellowish to green colour. The L*, a*, b* value was observed by the colourimeter. Where L*(luminosity – brightness), a* (greenness – redness), b*(yellowness – blueness). The objective of this study is to check the change in the physico-chemical composition and sensory properties due to the hot air assisted microwave drying.

EXPERIMENTAL METHODS

Sample collection and preparation :

The product used was the coffee (*Coffea Arabica* L.). Whole coffee fruits known as berries as well as de-pulped parchment coffee was collected from Coffee Research Station, Thandikudi (Western ghat), Dindigul district, Tamil Nadu, India (Latitude: 10.31, Longitude: 77.64, altitude: 1,500 m above sea level). De-pulped and washed parchment coffee sample (Arabica) was collected from farms with an initial moisture content of 49.6 ± 2 per cent (w.b). According to the literature, samples were stored inside the freezer for maintaining the moisture content with uniform temperate of 3^0C. Before starting an experiment, samples were kept in room temperature for 3 hours. Defected beans, damaged beans and foreign materials in the sample are manually removed before starting the experiment.

Hot air assisted microwave dryer :

Microwave dryer (Enerzi Microwave System, Model No – PTF-2515)was used for conducting the experiment. The dryer consists of two heaters and blowers as well as two magnetrons for heating and drying of the grains. A conveyor belt was attached with the machine for continuous drying of the food products.

Experimental procedure :

Coffee sample (in triplicate) was dried in normal sun drying method on metal tray placed on the concrete floor. In a single layer 1.5 kg of sample for three replication was used for drying. The drying area was 0.3364 m^2 and the loading density was 4.45 kg/m^2. The remaining sample was subjected to dry in the hot air assisted microwave dryer. According to review of literature and preliminary study, independent and dependent parameters were selected and experimental procedure was set up. Independent variables were Power level (0.5, 1.0, 1.5 kW) and Belt speed (5, 10, 15 mm/s). Dependent variables were chose as Moisture content, Physical parameters (mass, volume, bulk density), Colour value, Cup-testing (sensory analysis), Cholorogenic acid. No data was available on hot air assisted microwave drying of coffee beans in a conveyor. So, according to literature survey and the preliminary trials, 3 different power levels (0.5, 1.0 and 1.5kW) and 3 different conveyor belt speeds (5mm/s, 10mm/s, 15mm/s) with a residence time of 30 min were selected. Hot air temperature was set at 45^0C throughout the experiments. For each experiment 500g of coffee parchment was used. All the treatments were conducted in triplicate.

Moisture content determination :

According to International Organization Standardization – ISO 6673 (1983) each sample of whole coffee bean (3-5 g) was oven dried (Hot air oven - Everflow Scientific Instrument, India) at 105^0C for 24 h. The moisture content was calculated by dividing the mass changes of the beans by the initial mass and then times by 100 to obtain the per centage. The test was done in triplicate and the results averaged.

Physical parameters :

Mass-The mass was determined by a digital balance (Essae DS-852G, India) with an accuracy of 0.01 g.

Volume-Sample 150g was weighed and then filled in a 500ml measuring cylinder. The value obtained from the measuring cylinder reading was recorded.

Bulk density- The bulk density was determined by filling a sample in a 500 ml measuring cylinder. By dividing the mass of the filled sample by the cylinder volume, the bulk density was obtained. The test was done in triplicate and the results averaged (Chandrasekar and Viswanathan, 1999).

Colour value :

The colour of samples was observed using a colour meter (Hunter colourimeter, Colour Flex CFEZ-0925, USA).

Cup-testing :

Dried samples obtained with two different drying processes were used in the preparation of coffee drinks. The sensory classification used was "cup testing", performed by Coffee Board of India, based on a scale, from best to worst beverage. In case of sensory parameters aroma, body, acidity, flavour, mouth feel, after taste and overall acceptance was determined by the experienced coffee board panel member, Bengaluru, India.

Chlorogenic acid :

The chlorogenic acid (5-caffeoyilquinic acid) content was analyzed by high-performance liquid chromatography (HPLC) consisting of a LC-10ATVp pump, SCL 10A system controller and a variable Shimadzu SPD- 10 A Vp UV VIS detector and a loop injector with a loop size of 20 μl. The peak area was calculated with a CLASSVP software. Reverse-phase chromatographic analysis was carried out in isocratic conditions using a C-18 reverse phase column (250 × 4.6 mm i.d., particle size 5 μm, Luna 5μ C-18; phenomenex, Torrance, CA, USA) at 25°C. The mobile phase consisted of deionized water, methanol (HPLC grade) and acetic acid in the ratio of 85:15:1 at 1 mL/min flow rate (Franca *et al.*, 2005). The wavelength used was 278 nm. A chlorogenic acid standard solution was employed for the peak identification and quantitation (Ayelign and Sabally, 2013).

Standard solution preparation :

0.01g of CGA standard was dissolved in 100ml distilled water and 0.1, 1, 2.5, 5, 10, 50, and 100 ppm serial dilution of working standards were prepared.

Analytical determination, HPLC analysis :

100μl of the filtrate were diluted with 900 μl of deionised water and pipetted into clean 1000 μl volumetric flasks. The standards and the samples were run in the HPLC system. The following were the HPLC conditions: Column, Reverse phase – ODS, 250 × 4.6 mm, flow rate, 1 ml/min, detector, photodiode array set at 278 nm, maximum pressure, 400 kgf/cm^2, mobile phase, water, acetic acid, methanol (799, 1 and 200ml) and sample volume, 20 μl. A calibration curve of peak areas versus concentration of the standards was plotted.

Statistical analysis :

Statistical analysis is the best insight into a system to assist experiments. All the experiments for microwave drying and physico-chemical properties were determined in random order in triplicates. The physico-chemical properties were analysed by statistical program for social sciences (SPSS21.0, Chicago, IL, USA) software under analysis of variance (ANOVA) and least significance Difference test (LSD).The effect of microwave power levels and belt speeds on drying time and physico-chemical properties of parchment coffee were investigated using response surface methodology (Myers and Montgomery, 1995) by Design expert version 8.0.7.1 software (Stat-Ease Inc., Minneapolis, USA).

EXPERIMENTAL FINDINGS AND ANALYSIS

Total time taken for sun drying of coffee parchment was 3-5 days. One study was conducted in normal sun drying method at 32°C which took 23h which is equivalent to 3 days. Comparison of three different microwave treated sample with sun-dried sample was shown in Fig. 1. Heat generated in the microwave drying helped to dry the material very fast rather than sun drying. Combined effect of both the treatment had given the effective result. Drying time had a significant effect with power level but it had no significant effect with the belt speed (Fig 2).

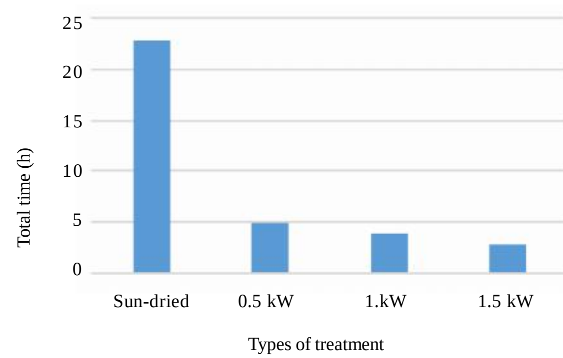

Fig. 1 : Comparison in total drying time

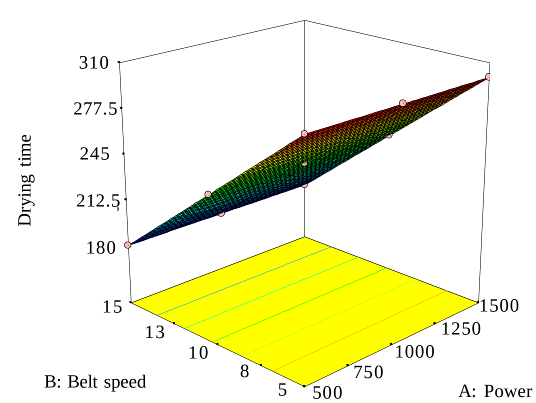

Fig. 2 : Response surface plot for drying time as a function of power level and belt speed

The details of drying result and value is discussed in (Payel and Sunil, 2014).

Changes in physico-chemical properties :

In case of physical properties of coffee, mass and volume plays the major role. In the industry and farm level purchasing of coffee is generally in the basis of volume. Effect of microwave power in the mass, volume and bulk density of the coffee had been studied (Fig. 3, 5 and 7).

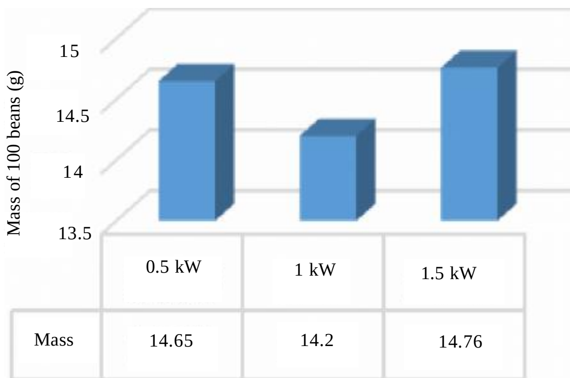

Fig. 3 : Changes in 100 beans mass with power level

From the (Fig. 3) it is clear that 100 bean mass decreased up to a certain microwave power level and then it increased with the increase in microwave power level where dried samples had a moisture content of 12 per cent (w.b).

Mass :

For power level of 1.5kW, mass was the maximum (14.76g) and in case of 1kW minimum mass(14.20g) can be obtained. With the comparison of sundried sample, sundried sample had the moisture content of 10.6per cent (w.b) with a 100 beans mass of 12.1g.

In case of coffee parchment there was a different trend noticed by (Chandrasekar and Viswanathan, 1999). In both the cases coffee parchment size did not increase with an increase in moisture content even when the mass increased. Therefore, expansion of coffee beans was not due to moisture absorption and probably some unknown factors are contributing for the expansion and increasing of mass. From the F statistics test and ANOVA table it was observed among the microwave treatments, 1kW gave the highest significant effect. Belt speed had no significant effect on the mass of the beans but power level had a significant effect (Fig. 4).

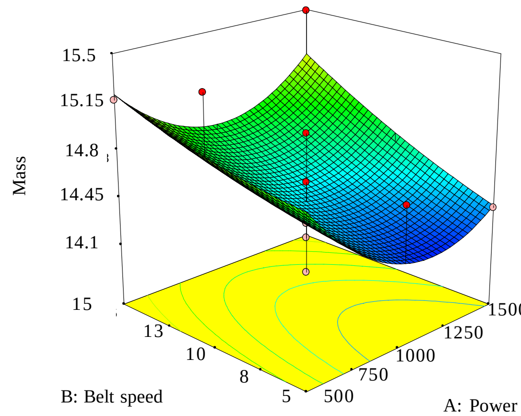

Fig. 4 : Response surface plot for mass as a function of power level and belt speed

Volume :

Volume of 150g of coffee bean was examined. Among the treatment combination considered sundried sample had the least volume as the moisture content was less. Among the microwave treated samples with a moisture content of 12 per cent (w.b), volume of 150g of sample was minimum (253.88ml) in 1.5kW and volume was maximum (257.77ml) in 1kW. So it could be concluded that 1kW was the optimum and the best power treatment.

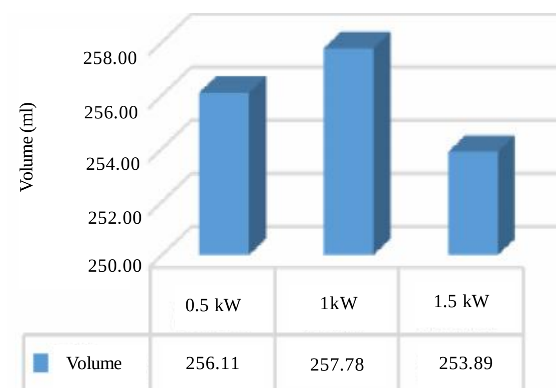

Fig. 5 : Changes in volume with power level

Similar result was reported by (Isamil *et al.*, 2012 and Chandrasekar and Viswanathan, 1999) in case of mass, volume and bulk density. In case of coffee parchment volume and bulk density increased with increase in mass. This trend was actually against the trend of other agricultural material such as gram, neem nut and groundnut. (Isamil *et al.*, 2012, Dutta *et al.*, 1988 and Baryeh, 2001), where the bulk density and volume decreased with increase in mass due to their size expansion.

F statistics test was performed and from the ANOVA table it was observed that F statistics value probability (0.001) was less than 0.05 (one ended F test).The treatment effects for microwave 1.5kW, 1kW, 0.5kW and sundried, means were 253.88, 257.77, 256.11 and 236.11, respectively. Among all the treatments 1kW sample had highly significant effect at 5 per cent significant level (Fig. 6).

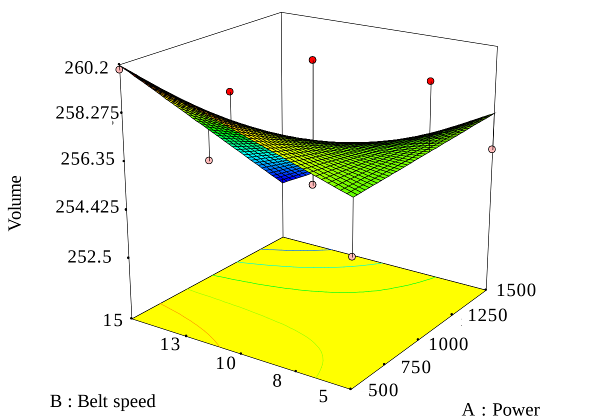

Fig. 6 : Response surface plots for volume as a function of power level and belt speed

Bulk density :

For sundried sample bulk density was 1.54g/ml whereas in case of microwave dried sample bulk density increased with the power level up-to 1kW then it decreased again. In case of 1.5 kW bulk density was minimum and in case of 1kW bulk density was maximum (1.71g/ml). Berbert *et al.* (2001) noticed that the changes in bulk density were greater at lower moistures than at higher moistures.

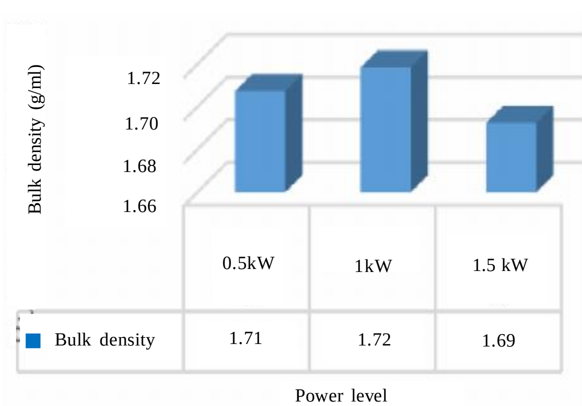

Fig. 7 : Changes in bulk density with power level

The treatment effects for microwave 1.5kW, 1kW, 0.5kW and sundried, means were 1.69, 1.71, 1.7 and 1.57, respectively. Among all the treatments 1kW sample had highly significant effect at 5 per cent significant level (Fig. 8).

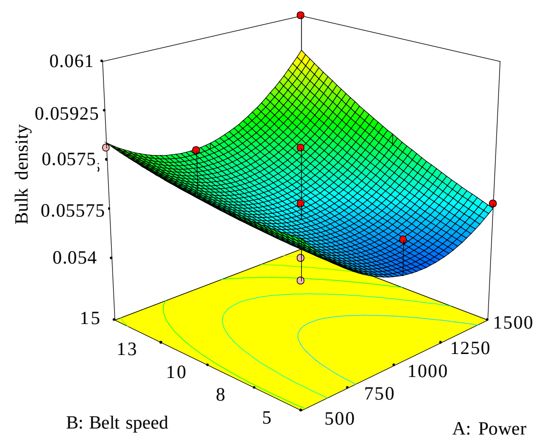

Fig. 8 : Response surface plots for bulk density as a function of power level and belt speed

Colour value :

Colour is another important parameter for judging the coffee quality. Colour of Dried coffee with parchment of all the treatments were same. But after removing the parchment and the silver skin, the original colour of the dried coffee bean was visible. After shelling the coffee parchment green colour was visible. Sundried coffee beans were brownish in colour. From the result it was found that the micro wave dried samples were more greenish in nature than the sundried sample. The green colour was determined by a* value. The decreasing trend of a* value was the indication of the increasing nature of greenness. Fig. 9 represents the changes in a* value with power level and belt speed.

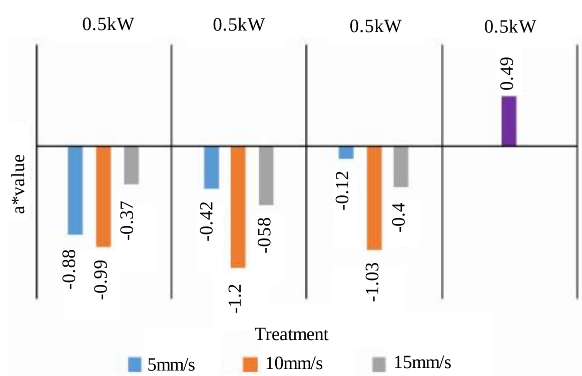

Fig. 9 : Changes in a* value with difference in power level and belt speed

The a* values decreased with increase in power level and increase in belt speed up to 1kW power level and then it decreased among the microwave treated samples. In case of sundried sample, it was brown in colour. Here negative value of a* value was the representation of the greenness of parchment coffee.

Nelson (2005) from Research Department Coffee Industry Board Kingston, Jamaica reported in the study of using colourimeter as analytical technique for quality assessment of green coffee beans that colourimeter can easily detect the difference between green bean, greenish bean and whitish and pale beans. The L, a* and b* value obtained for the pure green bean was 51.29, 1.3, 5.19, respectively. There was no data available of colour change for microwave dried coffee sample. The treatment effects for microwave 1.5kW, 1kW, 0.5kW and sundried, means were -0.53, -0.68, -0.47, 0.48, respectively. Among all the treatments 1kW sample had highly significant effect at 5 per cent significant level (Fig. 10).

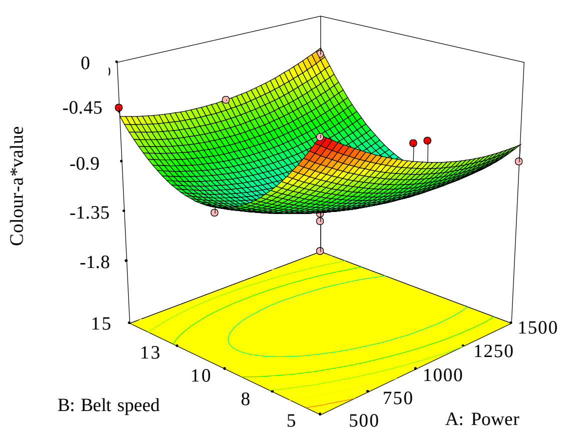

Fig. 10: Response surface plots for a* value as a function of power level and belt speed

Cup testing :

Sensory analysis of the coffee sample is known as 'cup testing'. It involved testing of body, acidity, flavour, aroma, mouth feel, after taste and overall quality of the beans after roasting. To interchange the qualitative values in quantitative manner, Coffee Board of India, Bangalore panel members' judgement was recorded for the documentation. Four different samples, *i.e.* sundried sample, and 3 different power level microwave dried sample were compared.

From the graph (Fig. 11) it was observed that microwave dried coffee samples were better or similarcompared with sundried sample. With the increase

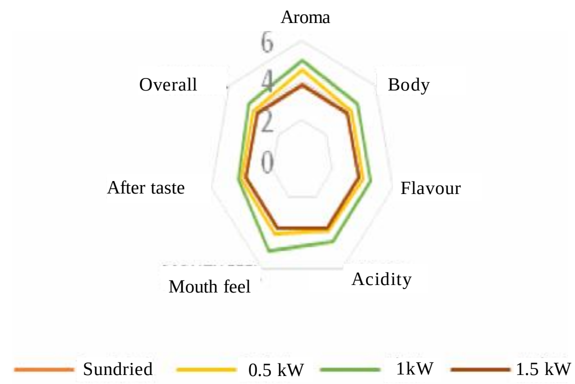

Fig. 11 : Effect of drying on sensory parameters

in microwave power level, the parameters increased up-to a certain level but at maximum power level the sensory parameters decreased. So, it was observed that 1kW power level was the optimum and suitable for microwave drying of parchment coffee. The treatment effects for microwave 1.5kW, 1kW, 0.5kW and sundried, means were 3.75, 4.7, 4.1 and 3.75, respectively. Among all the treatments 1kW sample had highly significant effect at 5per cent significant level (Fig. 12).

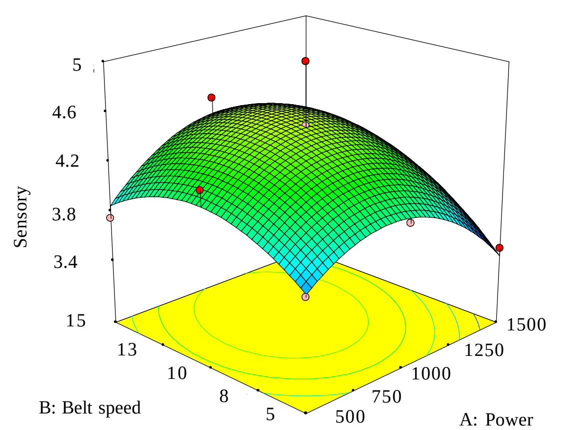

Fig. 12 :Response surface plots for sensory value as a function of power level and belt speed

Chlorogenic acid :

Data obtained from HPLC test in four different samples were shown in Fig. 13. There was a chance for the loss of chlorogenic acid or phenolic compounds inside the beans as in microwave heat was generating from inside to outside. But from the figure itself it is visible that microwave was not at all affecting the presence of chlorogenic acid. In case of sundried sample the amount was (17.76ppm) low due to the long-time exposure in sun light. In microwave dried treatment up-to 1kW the amount presence increased and in decrease up-to (12.45ppm) at 1.5kW. The maximum amount of chlorogenic acid in 1kW treated sample was 27.81ppm. It had a significant effect with the power level and belt speed.

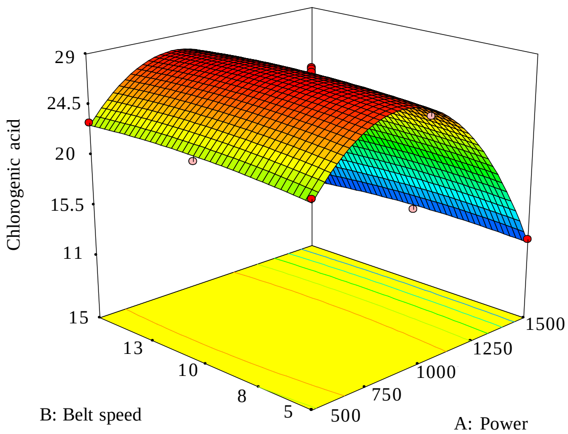

Fig. 13: Response surface plots for chlorogenic acid value as a function of Power level and belt speed

Isamil *et al.* (2012) reported that the presence of chlorogenic acid increased with increase in storage time. The level of CGA in green coffee beans reported by Clifford and Willson (1985); Trugo and Macrae (1984); Ky *et al.* (1997) and Ky *et al.* (2001) were about 4 - 8.4 per cent for Arabica coffee. On the other hand the content of CGA in various green coffee beans (21 species) from Cameroon and Congo ranged from 0.8 - 11.9 per cent on dry matter basis as reported by (Campa *et al.*, 2005). Perrone *et al.* (2008) reported a similar result with a total CGA contents for Arabica coffee 6.3 and 5.5 g/100 g using LC-MS. Percentage of CGA in various green coffee beans collected from south west of Ethiopia was in the range of [(6.05± 0.33) - (6.25±0.23) %] (Belay and Gholap, 2009).

Conclusion :

This study was undertaken to reduce the drying time for parchment coffee with the help of hot air assisted microwave dryer. This is the first attempt made for this type of drying in the field of coffee. 35kg of coffee was used in this study to investigate the drying kinetics as well as to study the physico-chemical properties. Three different microwave power level and three different belt speed was used. Power level had a significance effect on the drying time as well as on the physico-chemical properties. Whereas belt speed had no effect on the total drying of the product but had significant effect on the colour of the product.

It can be concluded that 100 bean mass decreased up to a certain microwave power level and then it increased with the increase in microwave power level where dried samples had a moisture content of 12 per cent (w.b), volume of 150g of sample was minimum (253.88ml) in 1.5kW and volume was maximum (257.77ml) in 1kW, Bulk density was minimum at 1.5kW and in case of 1kW bulk density was maximum (1.71g/ml).The a* value (greenness) decreased with increase in power level and increase in belt speed up to 1kW power level and then it decreased among the microwave treated samples. Cup testing score and chlorogenic acid content was maximum at 1kW power level.

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