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MICROWAVE DRYING OF BLACK TEA

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Microwave drying of black tea was carried out to investigate if microwave energy would completely inhibit the enzyme, polyphenol oxidase (PPO), activity in tea. PPO has a negative impact on the keeping qualities of tea, and its inhibition would improve keeping qualities while maintaining the tea character. Trials were initially conducted in the laboratory, and subsequently extended to the factory. Laboratory-scale samples were analysed for PPO activity and moisture content, while factory-scale samples were analysed for theaflavins (TF), thearubigins (TR), flavour compounds, moisture content, and subjected to taster's evaluation. It was found that PPO gets inactivated when fermented dhool is exposed to microwave energy.

Trials on microwave drying of broken-grade type manufacture using orthordox-rotorvane rollers, and leafy-grade type manufacture using orthodox rollers, indicate that in both instances the quality of the liquor is inferior to that of conventionally dried teas. However, the appearance in terms of blackness was better in microwave-dried teas.

Key Words: Tea, microwave drying, conventional drying, polyphenol oxidase.

INTRODUCTION

The enzymes, polyphenol oxidase (PPO) and peroxidase, play a major role during black-tea manufacture, namely in the formation of theaflavins (TFs) and thearubigins (TRs) during fermentation. These two enzymes mainly contribute to the quality of black tea. However, their prolonged activity converts TFs to TRs, and excessive amounts of TR pigments are organoleptically undesirable (Millin *et al.*, 1969).

PPO and peroxidase enzymes do not get completely denatured during conventional drying. As a result, during storage, if moisture is absorbed by the made tea, the enzymes get re-activated resulting in a decrease in the TF content and an increase in the TR content (Liyanage *et al.*. 1997). There is a possibility that modifications to existing driers may result in increased enzyme inactivation. In the present study, the possibilities of using microwave energy for the drying of tea was investigated.

Microwave technology has created an impact on modern society both as a means of cooking food and in the industrial preservation of food. Processing food products using microwave heating has been carried out in the past. The advantage of microwave heating, compared to conventional heating methods, is that the former generates heat within the food and is instantaneous, whereas in the conventional methods heat passes through the food from the outside to the inside, giving rise to a temperature gradient. Thus, more uniform heating is expected during microwave treatment (Gerling, 1986).

At present, microwave drying is used mainly for drying pasta and in the post-baking of biscuits in the food industry. However, several industrial microwave drying applications exist. Although the microwave drying of fruits and vegetables is hardly carried out on an industrial scale, at the research level a number of successful microwave drying attempts have been made. Microwave roasting of cocoa and coffee has been reported (Nijhuis *et al.*, 1998). In the manufacture of green tea, microwave energy has been used for the inactivation of PPO (Gulati *et al.*, 2003).

The microwave drying of black tea has been inadequately investigated. The objective of this study, therefore, was to determine if microwave energy would completely inhibit PPO activity in tea and improve its keeping qualities. Trials were initially conducted in the laboratory, and subsequently extended to the factory, for both broken-grade type manufacture using orthordox-rotorvane rollers, and leafy-grade type manufacture using orthodox rollers.

MATERIALS AND METHODS

Microwave treatment

(i) Laboratory trials

A domestic microwave oven (model: Gold Star MA 1066 ME, Korea) was used for drying. For enzyme inactivation studies, the first dhool after fermentation (prior to drying) was used. After initial experimentation at various power settings, the dhool was exposed to two power settings, namely 850 and 680 W. Initially, three batches of 100 g of dhool each were exposed to microwave exposure at 850 W for 3, 5 and 7 min. In the experiments that followed, five batches of 100 g dhool samples were exposed at 680 W for 3, 5, 7, 8 and 8.5 min., respectively. All the samples were subsequently assayed for PPO activity and their moisture content determined. As controls, unfired dhool, and dhool fired using the fluidised bed drier (FBD, was used.

Each trial was repeated three times, and the mean values of the parameters were recorded for comparison.

(ii) Trials on broken-grade type manufacture using orthordox-rotorvane rollers

Fermented dhool was dried in parallel, in the microwave oven and in the FBD (inlet temp. 255-260°F; outlet temp. 195-200°F; residence time; 21 min.), for comparison. A range of combinations with regard to extended fermentation time, and time of exposure to the microwaves, was tested, and the most desirable combinations were used. For microwave drying, 100 g of dhool were exposed at 680 W for 4.5 and 5.0 min. In addition, the same batch of dhool was fermented for an extended period of 45 min., and 100 g were exposed at 680 W for 4.5 and 5.0 min.

Each trial was repeated three times, and the mean values of the parameters were recorded for comparison.

(iii) Trials on leafy-grade type manufacture using orthodox rollers

Samples of fermented dhool of 100 g each were initially exposed at 680 W for 6.5 min., and then at a combination of power levels, namely 340 W for 3 min. and 680 W for 3.5 min. The same dhools were dried, simultaneously, in the endless chain pressure (ECP) drier (inlet temp. 195-200 °F; outlet temp. 135 °F; residence time 21 min.), for comparison.

Each trial was repeated three times, and the mean values of the parameters were recorded for comparison.

Preparation of extracts

The conventional pestle-and-mortar method, as described by Wickremasinghe and Perera (1972), was modified using a homogeniser and a high-speed centrifuge. One gramme of the tea samples was weighed into centrifuge tubes containing 0.5 g PVP to which 25 ml of cold McIlvaine buffer (pH 5.5) had been added. The sample was homogenised at 1200 rpm for 20 min. at 4°C, and the supernatant was used for the PPO assay. The temperature was maintained below 5°C during the extraction procedure.

Assay for PPO

The assay for PPO was carried out according to the procedure previously reported (Takeo and Baker, 1973).

Determination of TF, TR and total colour

TF, TR and total colour (TC) were determined by the method of Roberts and Smith (1961). Values are given on a dry-weight basis.

Determination of flavour compounds

Flavour compounds were determined by the method of Yamanishi *et al.* (1989).

Determination of moisture content

Moisture content was determined by the standard AOAC gravimetric method (1999).

Tasters' evaluations

A panel of three tasters performed sensory evaluation, and the average ratings were recorded for individual parameters. Infused leaf, colour, strength, quality and flavour were assessed.

RESULTS AND DISCUSSION

Laboratory trials

The desired moisture level of 3-4 % could not be achieved by exposing dhool to microwave energy at 850 W, for 3 and 5 min. The sample exposed at 850 W for 7 min. had a low moisture content and was devoid of any enzyme activity, although it had a dull infusion, thin liquor and a high-fired character (Table 1). All the samples dried using microwave energy had a better appearance with regard to blackness, than had the FBD-dried sample.

Table 1. Changes in PPO activity and moisture content in relation to microwave exposure at 850 W

sample (100g)	time of exposure min	%PPO activity in comparison to unfired dhool	moisture content %
dhool	3	13.6	39.3
dhool	5	8.4	14.7
dhool	7	0.0	2.4
controls			
dhool	-	100	61.1
black tea (FBD)	-	26	3.6

The PPO activity in the dhool was assumed to be 100%

In order to obtain a desirable product, the conditions were manipulated as follows. The power level was reduced to 680 W, and the time of exposure was set to 3, 5, 7, 8 and 8.5 mins. The moisture content and the PPO activity were monitored.

The results are given in Table 2.

Table 2. Changes in PPO activity and moisture content in relation to microwave exposure at 680 W

Sample (100 g)	Time of Exposure, min	% PPO Activity in comparison to unfired dhools	Moisture Content %
Dhool	3	8.7	49.28
Dhool	5	5.5	34.87
Dhool	7	3.2	13.91
Dhool	8	-	6.28
Dhool	8.5	-	3.51
Controls			
Dhool	-	100.0	58.53
Black tea (FBD)	-	26.0	3.66

The PPO activity in the dhools was assumed to be 100 %.

When teas were exposed at 680 W for 8 min. and above, the enzyme gets completely inactivated. Samples, exposed at 680 W for 8 and 8.5 min., tasted slightly better than those exposed at 850 W for 7 min. However, these liquors are not comparable to that from conventionally dried teas, although the appearance was superior to that of conventionally dried teas.

From the results obtained, it is observed that, although microwave energy could inhibit PPO activity completely, the quality of the liquor of the teas subjected to microwaves is not comparable to that of conventionally dried teas. However, teas dried in the microwave oven is blacker than conventionally dried teas.

Trials on broken-grade type manufacture using orthordox-rotorvane rollers

Having established that PPO activity is inhibited following microwave treatment, trials were extended to factory level at the Great Western Estate, Talawakelle. Fully-fermented dhools, dried in parallel in the microwave oven and in the FBD, were compared for moisture content, TF and TR content, flavour profile and taste.

Two sets of trials were carried out: one with normal fermentation, and the other with extended fermentation. For the extended fermentation trial, dhools were allowed to ferment for an additional 45 min. to compensate for the fermentation that occurs during conventional drying. It is known that PPO and peroxidase are still active at high temperatures (Liyanage *et al.*, 1997), and during conventional drying fermentation would continue inside the drier However, during microwave exposure, as a result of quick enzyme inactivation, fermentation does not take place.

The duration for extended fermentation was arrived at after experimenting over a range of time limits in order to get a desirable product. Each set was exposed at 680 W for 4.5 and 5.0 min., respectively, in an attempt to achieve the desired moisture content in the product.

The samples were analysed for TF, TR and moisture content (Table 3), and for flavour components (Table 4).

Table 3. Comparison of TF, TR and moisture content of microwave-dried teas with that of conventionally dried teas (broken-grade type manufacture)

Microwave treatment	% TF	% TR	% moisture
Fl (4.5 min.)	1.43	9.53	9.0
Fl (5.0 min.)	1.36	9.91	5.2
F2 (4.5 min.)	1.17	9.94	8.0
F2 (5.0 min.)	0.89	9.46	7.6
Control			
FBD	1.6	10.94	3.9

Fl - normal fermentation
F2 - extended fermentation (normal fermentation + 45 min.)
FBD - conventionaly dried teas using FBD (control)
TF- theaflavins, TR- thearubigins

Table 4. Comparison of volatile flavour compounds in microwave-dried teas with that in conventionally dried teas (broken-grade type manufacture)

Microwave Treatment	T-2-Hexenal ppm	Linalool I ppm	Linalool II ppm	Linalool ppm	Methyl salicylate ppm	Geraniol ppm
Fl (4.5mins)	4.36	0.19	1.02	2.08	1.04	4.17
Fl (5.0mins)	5.78	0.14	0.52	1.16	1.15	4.62
F2(4.5mins)	7.63	0.16	1.09	2.18	1.09	4.36
F2 (5.0mins)	6.23	0.15	0.89	1.51	1.12	4.22
Control						
FBD	37.83	0.51	2.56	5.11	3.07	6.65

Fl - normal fermentation

F2 - extended fermentation (normal fermentation + 45 min.)

FBD - conventionaly dried teas using FBD (control)

TF - theaflavins, TR - thearubigins

It was observed that using the microwave oven alone, it was not possible to keep the moisture content at the required level (Table 3). On the other hand, if the duration of microwave exposure is increased further, the teas tend to get burnt.

The percentage TF is lower in teas dried in the microwave oven than in teas dried using the conventional drier. The teas fermented for an extended period (F2, Table 3), and subsequently dried in the microwave oven, had even less amounts of TFs than teas undergoing normal fermentation (Fl, Table 3).

Analysis of the flavour profiles of samples revealed that individual flavour compounds were less in microwave-dried teas. On tasting, it was found that the liquors of teas dried in the microwave oven were thinner than those dried in the conventional drier. The flavour was less pronounced in the microwave-dried teas. The analyses for TF, TR and the flavour profiles confirmed these observations.

The infusions were duller in the microwave-dried teas than in conventionaly dried teas. However, the made tea was blacker in appearance in the microwave-dried teas than in conventionally dried teas.

Trials on leafy-grade type manufacture using orthodox rollers

A similar trial, with some modifications, on the time of exposure to microwave energy was conducted at the Watagoda factory, where the leafy-grade type of manufacture is being carried out, to test if this method would be suitable for low-country manufacture since low-country teas are valued for their appearance.

Fermented dhool was dried in parallel in the microwave oven and in the ECP. The fired teas were compared for moisture content, TF, TR, flavour profile and taste. The trials were repeated three times, and the average of these parameters were recorded and compared.

100 g each of fermented dhool was initially exposed at 680 W for 6.5 min., and then at a combination of power levels, namely 340 W for 3 min. and 680 W for 3.5 min. The samples were analysed for TF, TR and moisture content (Table 5).

Table 5. Comparison of TF, TR, TC and moisture content of microwave-dried teas with that of conventionally dried teas (leafy-grade type manufacture)

Microwave Treatment	%TF	%TR	TC	%moisture
F1 680W/6.5min	0.85	3.84	0.642	3.1
F1 340/3min + 680W/3.5min	0.84	3.65	0.650	4.1
Control ECP	1.03	4.11	0.938	3.1

F1 - normal fermentation
ECP - conventionally dried tea (control)
TF - theaflavins, TR – thearubigins

On comparing the results, it was observed that in microwave-dried teas the percentage TF is lower than in conventionally dried teas. The moisture content of the conventionally dried teas was comparable to that of the teas dried in the microwave at 680 W. The moisture content of the teas dried using a combination of power levels (340W/3 min. + 680W/3.5 min.) was higher than that of the teas dried at 680 W, and of the conventionally dried teas (Table 5).

On tasting, it was found that the liquors of teas dried in the microwave oven were thinner than those dried in the conventional drier. This was evident from the results of analyses for TF, TR and TC. The flavour was also less pronounced in microwave-dried teas, as shown in the results. The reduction of volatile flavour compounds after microwave drying may be due to the inactivation of enzymes forming volatiles, as well as loss of precursors. The infusions of microwave-dried teas were duller than that of conventionally dried teas. The appearance with reference to blackness of the teas, for all three samples, were similar to conventionally dried teas, owing to the high drier temperatures used in the leafy-grade type manufacture for achieving blacker dhools.

Future trials will be focussed on two-stage drying, the drying process which involves an initial convective drying (conventional drying) followed by a microwave finish drying. Microwaves may be advantageous in the last stage of air-drying because the least efficient portion of a conventional drying system is near the end, when two thirds of the time may be spent removing the last one third of the moisture content (Al-Duri and McIntyre, 1992). In addition, microwaves could inactivate PPO in made tea, and this would help improve the keeping qualities (Liyanage *et al.*, 1997).

CONCLUSIONS

Overall, the results indicate that, when the microwave oven has been used to dry both broken-grade type and leafy-grade type teas, the quality of the liquor is inferior to that of conventionally dried teas in both instances. However, the appearance of the broken-grade type of teas, dried in the microwave oven, was superior to that of conventionally dried teas. In the case of the leafy-grade type of teas, the appearance was similar in teas dried in the microwave oven and by the conventional method.

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