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TECHNICAL NOTE

Effects of storage time in a two-stage withering process on the quality of seedling black tea

Philip O. Owuor & John E. Orchard*

Tea Research Foundation of Kenya, PO Box 820, Kericho, Kenya

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Variation of chemical wither time by up to 18 h in the manufacture of black tea, from shoots of seedling tea, caused minimal changes in plain tea quality parameters. Thus, in a two-stage wither, plain black teas can be withered for between 0 and 18 h without loss or improvement in quality. Both the Group I volatile flavour compounds (VFC), and Group II VFC decreased with chemical wither time, but the decrease in Group I VFC was much higher, resulting in improvement of flavour index with chemical wither time. The changes in the VFC did not significantly change the tasters' evaluations which seemed to follow the plain tea quality parameters.

INTRODUCTION

The manufacture of black tea from young tender shoots of *Camellia sinensis* (L.) O. Kuntze involves five major steps: withering, maceration, fermentation, firing (drying) and sorting. Of these steps, withering takes the largest factory space (Owuor *et al.*, 1987).

Black tea production in Kenya is increasing steadily and very rapidly. In 1980 Kenya produced 89 893 metric tonnes (Anon, 1990) which rose to 197 008 tonnes in 1990 (Anon, 1991). Thus, within 10 years black tea production increased more than two-fold. This rapid rise in production has not been matched with concurrent increase in factory space. The step most affected in manufacture has been withering, as the space to keep and wither the leaf has been too limited. This situation has warranted a search for more space-economical and/or different, faster methods of withering for the processing of the leaf.

Using clonal tea, it has been demonstrated that a two-stage wither, where leaf is first stored in a holding unit to achieve chemical wither and then subjected to a short forced physical wither (moisture loss) by use of high volume of fast moving air or warm air, did not significantly change quality compared to a normal one-stage wither, where leaf is put on a withering trough for 12–18 h to achieve physical and chemical withers simultaneously (Owuor *et al.*, 1987; 1989; Owuor & Orchard, 1989*a*). Ullah (1984*a*) had also obtained similar results.

Most black teas from Western Kenya, especially from the commercial large estates, are manufactured from seedling tea plants. The black teas from such plants are classified as plain to medium. In the authors' earlier studies, high quality to better medium clonal flavoury teas were used (Owuor *et al.*, 1987, 1989). The chemical parameters responsible for the qualities of these two groups of black tea are different. This study was therefore undertaken in part to quantify the changes in the quality parameters of plain to medium black teas in a two-stage withering condition.

In the production of flavoury black tea, chemical withering is known to be essential (Bhatia, 1962; Dev Choudhury & Bajaj, 1980; Saijo, 1977; Takeo, 1984). Similar observations have also been observed for high quality clonal teas in Kenya (Owuor *et al.*, 1987, 1989). However, the effects of chemical wither on the quality of plain to medium teas are unknown. Earlier, it had been demonstrated that the plain tea quality parameters are reduced if the chemical wither of high quality clonal tea is continued beyond 20 h (Owuor *et al.*, 1990). Ullah (1984*b*) noted that optimum chemical wither required 14 h. However, the benefits from such chemical wither on plain teas have not been

* Present address: Natural Resources Institute, Central Avenue, Chatham Maritime, Kent, ME4 4TB, UK.

documented. This study was undertaken to assess if such optimum chemical wither time exists for plain teas. The results of the study to examine the variations of chemical wither time of seedling black tea are reported herein.

MATERIALS AND METHODS

Manufacture

Young tender shoots of seedling tea were plucked from commercial fields using the normal commercial plucking standard which consist mainly of soft shoots of two leaves and a bud and three leaves and a bud. The shoots were chemically withered for 0, 4, 7, 10, 14 and 18 h in a holding tank with minimal air flow, just enough to dissipate any heat developed. After the withering period was over the leaf was loaded on to a moving-belt withering machine with perforations to allow free air flow. Air was blown through the belt starting at 50°C at the beginning of physical wither and dropping the temperature by 5°C every 12 min so that after one hour the temperature was 25°C. During this process the leaf had a residual moisture content of 68–70%. Thus, each chemical withering period was followed by one hour physical wither.

The withered leaf was macerated using a rotorvane machine followed by three 'crush, tear and curl' (CTC) machines in series, then fermented for 120 min. The tea was dried using a fluid bed drier. The dried tea was sorted (graded) and 1 kg of PF1 grade was obtained for chemical analysis and sensory evaluations. The experiment was done in triplicate on two different occasions.

Chemical analysis

For plain tea quality parameters, the teas from each manufacture were divided into three and analysed in triplicate. Means from each analysis from the two manufactures were used to carry out analysis of variance.

Theaflavins (TF) were analysed by the method of Hilton (1973) and thearubigins (TR), colour and brightness were determined by the Roberts and Smith (1963) method. Caffeine was quantified by the method of Cloughley (1982) as outlined by Owuor *et al.* (1986).

The volatile flavour compounds (VFC) were extracted by simultaneous steam distillation extraction (water/diethyl ether) method (Likens & Nickerson, 1964) using methylpalmitate as an internal standard (Owuor *et al.*, 1986, 1987, 1989, 1990). GC analysis was performed under the conditions of Baruah *et al.* (1986). The amounts of the VFC are given as the ratio of the GC peak areas of the components to that of the internal standard (Baruah *et al.*, 1986; Owuor *et al.*, 1986, 1987, 1989, 1990). The VFC were grouped into Group I VFC (compounds imparting inferior grassy aroma to black tea) and Group II VFC (compounds imparting sweet flowery aroma to black tea). The ratio of Group II to Group I (the flavour index, FI) was used to classify the teas in their aroma quality order (Owuor *et al.*, 1986; 1987, 1988, 1989, 1990). FI is qualitative in nature since the olfactory perception limits of the different VFC are different. Some VFC could not exist at low levels and affect the aroma more than those which exist in larger quantities, and vice versa (Kobayashi *et al.*, 1988).

Sensory evaluation

After each manufacture, samples for sensory evaluation were forwarded to one buyer/manufacturer and five different tea brokers based in Mombasa who evaluated the teas independently and blindly. The teas were evaluated for briskness, brightness, colour, infusion, flavour and overall quality in a scale of 0–10 for each attribute. The scores from individual tasters need to be evaluated independently since their scores cannot be standardised.

Table 1. Changes in plain tea quality parameters of black tea from leaf subjected to different storage periods during two-stage withering.

Chemical wither (storage period hours)	TF µmol/g	TR (%)	Colour (%)	Brightness (%)	Caffeine (%)
0	16·9	13·4	4·34	2·14	2·76
4	18·4	15·4	4·85	18·8	2·88
7	18·1	13·9	4·59	21·3	2·84
10	18·4	14·8	4·46	23·2	2·89
14	18·8	13·9	4·53	22·7	2·71
18	17·5	14·4	4·50	19·0	2·79
CV %	3·67	5·71	5·62	9·11	2·59
LSD $P \leq 0{\cdot}05$	1·20	NS	NS	NS	NS

LSD, Least square difference
NS, Not significant

RESULTS AND DISCUSSION

Benefits of withering in tea manufacture were recently reviewed (Owuor & Orchard, 1989*b*) and in this study withering time was limited to 18 h since it had been demonstrated that withering beyond 20 h impaired black tea quality (Owuor *et al.*, 1990).

Seedling teas grown in the western Kenya highlands generally make plain teas (Owuor & Orchard, 1990). Such teas normally have high TF but flavour indices are below 1. The changes in the plain tea quality parameters, namely, TF, thearubigins, caffeine, are presented in Table 1. The plain teas are usually valued for their brightness which is normally attributed to TF and colour which is attributed to TR. The changes in the brightness and colour, as measured spectrophotometrically, are also presented in Table 1. Chemical wither for 4–14 h resulted in significantly higher TF than for teas manufactured without chemical wither. Thus, for plain black teas made from western Kenya seedling

Table 2. Variations in the composition[a] of the volatile flavour compounds due to chemical wither time in two-stage withering manufacture

VFC	Chemical wither time (h)					
	0	4	7	10	14	18
2-Methyl butanal	0·03	0·02	0·03	0·03	0·03	0·02
Pentanal	0·05	0·05	0·04	0·03	0·04	0·04
Hexanal	0·62	0·54	0·35	0·29	0·29	0·26
1-Penten-3-ol	0·11	0·10	0·07	0·07	0·06	0·07
Heptanal	0·02	0·02	0·02	0·01	0·01	0·01
Z-3-Hexenal	0·27	0·19	0·13	0·14	0·11	0·11
E-2-Hexenal	2·98	2·73	2·54	2·30	2·17	2·05
n-Pentanol	0·02	0·02	0·02	0·02	0·02	0·01
Z-2-Penten-1-ol	0·14	0·13	0·10	0·08	0·09	0·09
n-Hexenol	0·06	0·05	0·04	0·02	0·03	0·03
Z-3-Hexen-1-ol	0·19	0·17	0·11	0·09	0·07	0·07
Nonanal	0·06	0·04	0·04	0·03	0·02	0·02
E-2-Hexen-1-ol	0·03	0·04	0·04	0·03	0·02	0·02
E,Z-2,4-Heptadienal	0·04	0·03	0·03	0·03	0·02	0·02
E,E-2,4-Heptadienal	0·03	0·02	0·02	0·02	0·02	0·02
Sum of Group I VFC	4·65	4·15	3·57	3·19	3·01	2·83
Linalool oxide (*cis*-furanoid)	0·10	0·09	0·08	0·07	0·06	0·07
Linalool oxide (*trans*-furanoid)	0·34	0·33	0·29	0·22	0·21	0·18
Benzaldehyde	0·05	0·04	0·04	0·04	0·03	0·03
Linalool	1·17	1·13	0·98	0·90	0·80	0·86
α-Cedrene	0·07	0·03	0·04	0·05	0·04	0·03
β-Cedrene	0·01	0·02	0·01	0·02	0·01	0·01
3,7-Dimethyl-1,5,7-octatrien-3-ol	0·01	0·01	0·02	0·02	0·02	0·01
β-Cyclocitral	0·02	0·03	0·03	0·03	0·02	0·02
Phenylacetaldehyde	0·14	0·19	0·18	0·17	0·16	0·14
Neral	0·06	0·05	0·05	0·04	0·05	0·04
α-Terpineol	0·06	0·06	0·06	0·06	0·05	0·04
Linalool oxide (*cis*-pyranoid)	0·02	0·02	0·01	0·02	0·03	0·01
Methyl salicylate	0·22	0·24	0·22	0·19	0·17	0·17
Nerol	0·04	0·03	0·03	0·03	0·03	0·02
Geraniol	0·30	0·37	0·32	0·40	0·44	0·42
Benzyl alcohol	0·03	0·02	0·02	0·02	0·02	0·02
2-Phenylethanol	0·08	0·09	0·08	0·07	0·08	0·07
β-Ionone	0·04	0·03	0·03	0·03	0·03	0·03
5,6-Epoxy-β-ionone	0·04	0·03	0·04	0·03	0·04	0·02
Nerolidol	0·05	0·05	0·04	0·05	0·05	0·03
Cedrol	0·04	0·03	0·04	0·01	0·03	0·05
Bovolide	0·01	0·01	0·01	0·01	0·01	0·01
Methyl palmitate	0·01	0·02	0·01	0·01	0·02	0·01
6,10,14-Trimethyl pentadecan-2-one	0·02	0·02	0·02	0·02	0·02	0·02
E-Geranic acid	0·03	0·03	0·03	0·04	0·02	0·03
Sum of Group II VFC	2·96	2·97	2·68	2·55	2·54	2·34
Flavour Index[b]	0·64	0·72	0·75	0·80	0·84	0·83

[a] As ratio of the gas chromatographic peak area of the compound to that of internal standard.
[b] As ratio of sum of Group II/Group I VFC.

Table 3. Changes in tasters' evaluations[a] of black tea due to variation in storage period in two-stage withering

Chemical wither time (h)	Taster					
	A	B	C	D	E	F
0	40	28	26	37	34	31
4	37	28	24	36	44	30
7	36	29	19	33	41	31
10	39	31	23	37	35	32
14	38	29	27	36	44	30
18	41	36	20	37	37	31

[a] Based on sums of briskness, brightness, colour, flavour and quality on a scale of 0–10 for each factor. Average of two different independent tastings.

teas, chemical wither times between 4 and 14 h did not appear to change the TF development.

The TR, caffeine, colour and brightness did not change with change in chemical wither time. In earlier studies using high quality clonal materials, significant variations were noted in the plain tea quality parameters due to chemical wither time (Owuor *et al.*, 1987. 1989, 1990). The lack of any significant changes attributable to chemical wither time here is due to the large genetic variability in the seedling material used. All the plants in seedling tea plantations are genetically different since tea is open-pollinated. The changes caused by the genetic variability seemed higher than the changes caused by the chemical wither time. It is also noted that the spectrophotometric methods to measure TR, colour and brightness are subject to interference by flavonol glycosides (McDowell *et al.*, 1990).

Many studies have demonstrated that the benefits in the aroma character of black tea due to chemical withering (Saijo, 1977; Takeo, 1984; Owuor *et al.*, 1987, 1989, 1990). The changes in the VFC composition with varying chemical wither time are presented in Table 2. There was a general decrease in both the total Group I and Group II VFC with increase in the chemical wither time. The decrease in the Group I VFC was faster than that in Group II VFC, resulting in the improvement of FI with chemical wither time. FI had been demonstrated to be a quality parameter of some Kenyan teas (Owuor *et al.*, 1988). Although chemical wither time improved the FI, the changes were minimal and remained below 1. Thus, the teas remained inherently plain. The improvement was therefore minimal and inconsequential to the general quality.

Tasters' evaluations are normally criticised as subjective and influenced by many factors outside quality, such as personal preferences, supply and demand. However, it remains the most practical method of quality assessment in the tea trade, mainly due to its being fast and not requiring any instrumentation. The changes in tasters' evaluations with withering time are presented in Table 3. There was no clear pattern to the evaluations when the different tasters were compared. This strengthens the subjective nature of this method for quality evaluations as personal preferences for different teas are clearly demonstrated. For each taster, again there did not appear to be a clear trend in the order of preference depending on chemical wither time. Thus, any wither time could be used to manufacture plain tea without serious deterioration.

All the black teas manufactured were of commercial grade, but were classified as plain. Thus, in conclusion, in the manufacture of plain teas from seedling materials in western Kenya, variations in chemical wither time have no significant effect. This result is of importance in the manufacture of black tea during peak crop (maximum production) periods when the factory capacities are limiting. Generally, during these periods, the manufactured teas are plain (Owuor *et al.*, 1991) due to the fast growth conditions. If withering is shortened, one withering trough may be used more than once in one day, thus enabling the factory to accept more leaf.

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REFERENCES

Anon. (1990). Annual bulletin of statistics. International Tea Committee. 32 pp.

Anon (1991). Record production for Kenya tea—1990. *Tea Times*, **16**, 6–8.

Baruah. S., Hazarika, M., Mahanta, P. K., Horita, H. and Murai, T. (1986). Effect of plucking intervals on the chemical constituents of CTC black teas. *Agric. Biol. Chem.*, **50**, 1039–41.

Bhatia, I. S. (1962). Chemical aspects of withering. *Two and a Bud.*, **9**, 26–30.

Cloughley, J. B. (1982). Factors influencing caffeine content of black tea. Part 1. The effect of field variables. *Food Chem.*, **9**, 269–76.

Dev Choudhury, M. N. & Bajaj, K. L. (1980). Biochemical changes during withering of tea shoots. *Two and a Bud*, **27**, 13–6.

Hilton, P. J. (1973). Tea. In *Encyclopedia of Industrial Chemical Analysis Vol. 8*, ed. F. D. Snell & L. S. Ettre. John Wiley, New York. pp. 455–526.

Kobayashi, A., Kawamura, M., Yamamoto, Y., Shimizu, K., Kubota, K. & Yamanishi, T. (1988). Methyl epijasmonate in the essential oil of tea. *Agric. Biol. Chem.*, **52**, 2299–303.

Likens, L. S. & Nickerson, C. B. (1964). Detection of certain hop oil constituents in brewing products. *Proc. Amer. Soc. Brew. Chem.*, 5–13.

McDowell, I., Bailey, R. G. & Howard, G. (1990). Flavonol glycosides of black tea. *J. Sci. Food Agric.*, **53**, 411–4.
Owuor, P. O. & Orchard, J. E. (1989*a*). The effects of degree of physical wither on the chemical composition of black teas. *Tea*, **10**, 47–52.
Owuor, P. O. & Orchard, J. E. (1989*b*). Changes in biochemical constituents of green leaf and black tea due to withering. A review. *Tea*, **10**, 53–9.
Owuor, P. O. & Orchard, J. E. (1990). Changes in the quality and chemical composition of black tea due to physical wither, condition and duration of fermentation. *Tea*, **11**, 109–17.
Owuor,. P. O., Orchard, J. E., Robinson, J. M. & Taylor, S. J. (1990). Variations in the chemical composition of clonal black tea due to delayed withering. *J. Sci. Food Agric.*, **52**, 55–61.
Owuor, P. O., Othieno, C. O., Robinson, J. M. & Baker, D. M. (1991). Response of tea to quality parameters to time of the year and nitrogen fertilizers. *J. Sci. Food Agric.*, **55**, 1–11.
Owuor, P. O., Tsushida, T., Horita, H. & Murai, T. (1986). Comparison of the chemical composition of black teas from main tea producing parts of the world. *Tea*, **7**, 71–8.
Owuor, P. O., Tsushida, T., Horita, H. & Murai, T. (1987). Effects of artificial withering on the chemical composition and quality of black tea. *Trop. Sci.*, **27**, 159—66.
Owuor, P. O., Tsushida, T., Horita, H. & Murai, T. (1988). Effects of geographical area of production on the volatile flavour compounds in Kenyan clonal black CTC teas. *Expl. Agric.*, **24**, 227–35.
Owuor, P. O., Wanyiera, J. O., Njeru, K. E., Munavu, R. M. & Bhatt, B. M. (1989). Comparison of the chemical composition and quality changes due to different withering methods in black tea manufacture. *Trop. Sci.*, **29**, 207–13.
Roberts, E. A. H. & Smith, R. F. (1963). Phenolic substances of manufactured tea. II. Spectrophotometric evaluation of tea liquors. *J. Sci. Food Agric.*, **14**, 689–700.
Saijo, R. (1977). Mechanism of developing black tea aroma with special reference to alcoholic compounds. *Japan Agric. Res. Quart.*, **11**, 216–20.
Takeo, T. (1984). Effect of withering process on volatile flavour compound formation during black tea manufacture. *J. Sci. Food Agric.*, **35**, 84–7.
Ullah, M. R. (1984*a*). A reappraisal of withering process in black tea manufacture I. Chemical withers and their effects on liquors. *Two and a Bud*, **31**, 20–4.
Ullah, M. R. (1984*b*). A reappraisal of withering process in black tea manufacture I. Physical and chemical wither in current practises of artificial withering and its effects on tea liquors. *Two and a Bud*, **31**, 24–7.