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The determination of optimum fermentation time in Turkish black tea manufacture

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In recent years, Turkish black tea has been manufactured by a combination of orthodox + rotorvane + orthodox systems, especially developed for the conditions of Turkey. The optimum fermentation time of black tea manufactured by this system was investigated at the factory level by measuring the theaflavin contents during the fermentation step, which starts with rolling and ends with drying processes. Optimum fermentation times from the start of rolling in the ORO system were determined to be 83 min and 80 min for coarse tea and sieved fine tea, respectively, by theaflavin analysis. Low levels of theaflavin in Turkish black tea were attributed to the very low quality of the fresh tea leaves and of the plucking standards. © 1997 Elsevier Science Ltd

INTRODUCTION

Beverage tea made from the young tender shoots of *Camellia sinensis* (L.) O. Kuntze is the most widely consumed non-alcoholic drink in Turkey. The annual tea consumption is about 2.3 kg per capita and this level of consumption is higher than world standards, being exceeded only by the UK and Ireland. In addition, Turkey is the world's fifth largest producer of black tea, accounting for some 8% of world output. National production has expanded rapidly from 96 000 tons in 1980 to 170 000 tons in 1994 (Schallies *et al.*, 1994), and there are 202 000 producers, cultivating a total area of 76 600 ha in the Eastern Black Sea part of Turkey. The plantations have been established with a hybrid dominated by the Chinese variety (Oksüz & Kayíkcí, 1993).

Black tea manufacture is carried out by a series of processes on fresh tea leaves, involving withering, rolling, fermentation, drying and sieving (Werkhoven, 1974). Fermentation is one of the critical steps, most of the significant chemical transformations occurring during this phase (Roberts, 1958*a*). Tea shoots contain appreciable amounts of flavanols, which undergo oxidative and condensative transformations during fermentation, giving rise to two main groups of coloured compounds, the theaflavins (TF) and the thearubigins (TR). The reactions are affected by temperature, moisture, oxygen availability, physical and genetic properties of tea leaves, rolling conditions and fermentation time (Hilton & Ellis, 1972; Abdul-Gaffar *et al.*, 1980; Owuor *et al.*, 1986, 1987*a*; Hilton & Palmer-Jones, 1975; Malec & Vigo, 1988). It has been shown that significant correlations exist between black tea quality and TF content. As a result, the TF value of black tea was proposed as a measurable and useful indicator for tea quality (Roberts, 1958*b*; Owuor, 1982; Davies, 1983; Hilton & Palmer-Jones, 1973; Owuor *et al.*, 1987*b*; McDowell *et al.*, 1991). The practice in factories is that the time at which to stop fermentation is judged by the visual assessment of the 'dhool' (fermenting macerated leaf). Because visual assessment is subjective, various attempts have been made to determine the extent of fermentation quantitatively, and several groups have reported on the relationship between time and TF formation in the fermentation step (Philip & Reeves, 1986; Owuor, 1987; Cloughley, 1979; Owuor & Reeves, 1986; Roberts & Chandradasa, 1982).

In tea manufacture, it is very important for the optimum fermentation time to be determined objectively. In this work, we present our investigations on optimum fermentation time for Turkish black tea processed by orthodox + rotorvane + orthodox (ORO) systems at factory level.

MATERIALS AND METHODS

Tea leaves and manufacture

Green tea leaves were plucked from the Islampasa-Rize plantation (at sea level) within four periods; the May (period 1), June (period 2), August (period 3) and October (period 4) shooting periods for the year 1995

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were used as material in the Cumhuriyet Tea Plant (Rize) for production of black tea by the Cay-Kur system, a combination of ORO manufacture (Vanlí *et al.*, 1987). About 30–35% of the structural moisture in the fresh tea leaves was evaporated by artificial withering at 32°C for 6 h in a trough, then the leaves were subjected to the first rolling process in the ORO system for 45 min. Rolled leaves passed through a rotorvane on a carrier band within 6 min. The macerated tea leaves in the rotorvane were passed through a double wet tea sieve in 2 min and the sieved fine tea was directly transported to the fermentation unit. Coarse tea was loaded onto a conical rolling machine for an additional 20 min of rolling, then transported to the fermentation unit. After different fermentation periods, the tea samples were dried at 95–100°C in a miniature tea-drier, and ground. Black tea manufacturing processes (boxes) by the Cay-Kur system (ORO) and tea samples taken at each step (numbers) are outlined in Fig. 1.

Chemical analysis

TF analysis was done on dried tea samples using the Flavognost method (Hilton, 1973; Reeves *et al.*, 1985). The percentage of dry matter in the sample was determined by oven-drying. A tea infusion was made with 125 ml of boiling water (preferably added from an overhead boiler into a tared flask) and 3 g of tea, and the mixture shaken for 10 min. The infusion was filtered through cotton wool, and 10 ml were pipetted into 10 ml of isobutylmethyl ketone (IBMK). The mixture was shaken for 10 min and allowed to stand until the layers

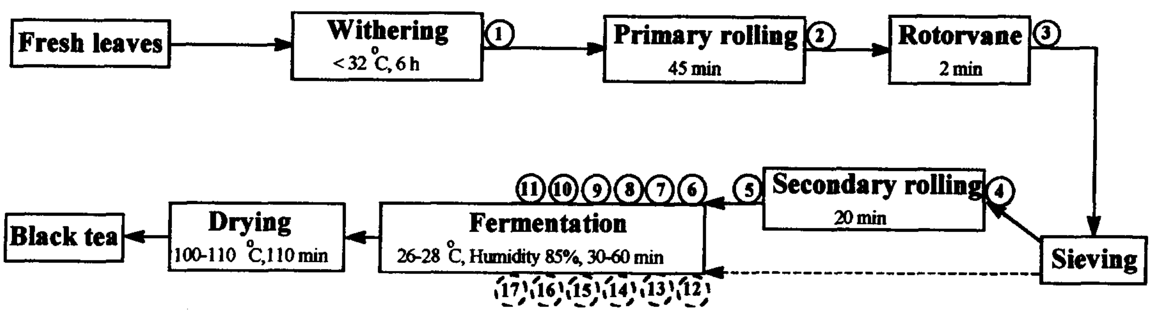

Fig. 1. A representation of Turkish black tea manufacture by the Cay-Kur system (ORO) and the tea sampling points. 1, the point where oxidation starts; 2 and 3, the oxidation periods (45 and 47 min, respectively) from the start; 4–11, oxidation times (50, 70, 73, 83, 93, 103, 113 and 123 min, respectively) from the starting point for coarse tea samples; 12–17, oxidation times (50, 60, 70, 80, 90 and 100 min, respectively) from the starting point for fine tea samples.

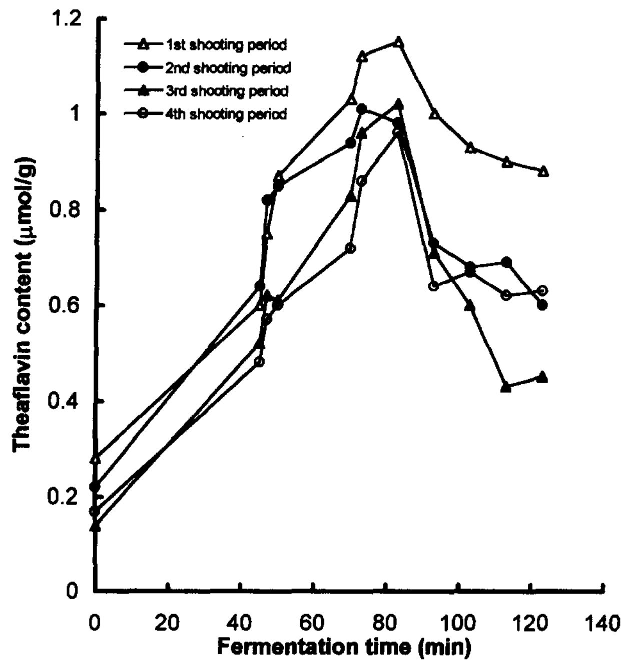

Fig. 2. Theaflavin content of coarse tea samples with regard to fermentation time in black tea processing by the Cay-Kur system for the different shooting periods (see Introduction for details).

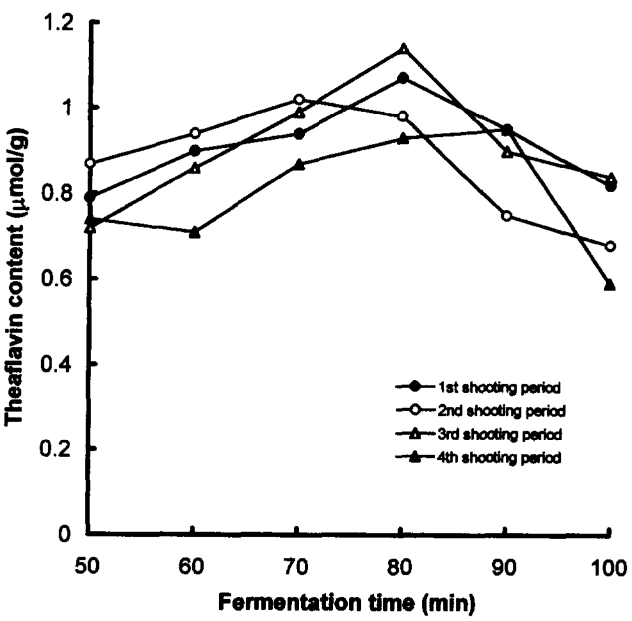

Fig. 3. Theaflavin content of fine tea samples with regard to fermentation time in black tea processing by the Cay-Kur system for the different shooting periods (see Introduction for details).

separated. Then 2 ml of the upper layer were pipetted into a test tube followed by 4 ml of ethanol and 2 ml of Flavognost reagent (2 g of diphenylboric acid 2-aminoethyl ester dissolved in 100 ml of ethanol). The contents of the test tube were mixed and the colour was allowed to develop for 15 min. The absorbance at 625 nm was read against a blank of IBMK–ethanol (1:1). The TF level was calculated as reported (Hilton, 1973; Reeves *et al.*, 1985).

RESULTS AND DISCUSSION

The points at which tea samples were taken for TF content determination during the fermentation stage of the Cay-Kur system (ORO), which starts with rolling and ends with drying processes, are indicated in Fig. 1. The TF contents of the tea samples prepared from the coarse and sieved fine tea samples that were directly transported to the fermentation unit are depicted in Figs 2 and 3 for each shooting period in the year 1995. Ten replicates of tea samples from each point of sampling were submitted to ANOVA. The results showed that there were no statistical significantly differences ($P > 0.05$) among the samples, and mean values were therefore used in the figures.

Green leaf of high quality is the first prerequisite for quality and success in black tea manufacture. The processes in tea manufacture have to be evaluated as a whole, together with the green leaf. Tea manufacturing countries try to develop their product norms and manufacturing methods in order to achieve the best quality in the processed tea as dictated by market demands. Recently, it was demonstrated that the most suitable system in Turkey is the Cay-Kur system (ORO) along with the rolling (orthodox) system (Vanlí *et al.*, 1987).

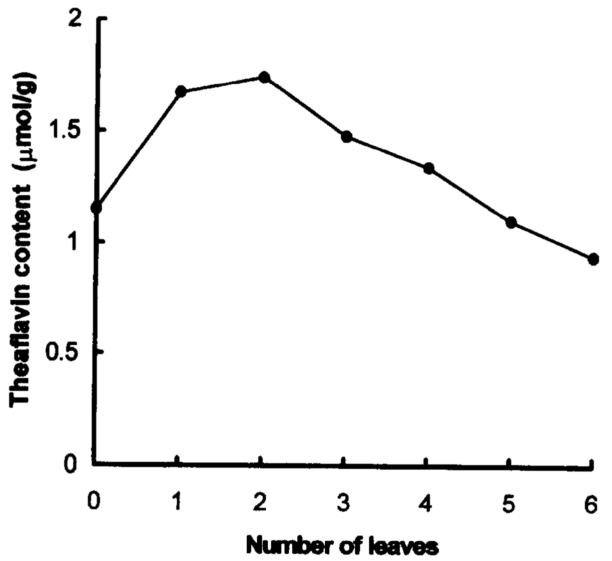

Fig. 4. Theaflavin content of Turkish black tea with regard to plucking standards (numbers on x-axis represent the number of leaves together with the bud, zero implying the bud only).

Optimum fermentation times from the start of rolling in the ORO system were determined by TF analysis to be 83 min for coarse tea (Fig. 2) and 80 min for sieved fine tea (Fig. 3). Lower TF contents were obtained at longer oxidation times, presumably due to transformation of TF to TR (Cloughley, 1979). The accurate and objective determination of the optimum fermentation time is of great economic importance, especially when it is considered that the rate of fermentation and of TF production is profoundly influenced by a range of factors, such as genetic constitution of the leaf, seasonal and climatic factors, agronomic and cultural practices, and systems of manufacture (Abdul-Gaffar *et al.*, 1980; Owuor *et al.*, 1987*a*; Malec & Vigo, 1988; Hilton & Palmer-Jones, 1973; Cloughley, 1980; Owuor *et al.*, 1994).

The effect of plucking standards on TF content is shown in Fig. 4. With two leaves and a bud, the TF values reached a maximum. Decrease in TF levels due to additional leaves is probably due to lower levels of polyphenol and polyphenol oxidase activity (Thanaraj & Seshadri, 1990), which were not monitored in this study. This aspect will be the subject of further experimentation. The most important reason for low quality in tea production in Turkey is shear-plucking. Although mechanical harvesters improve productivity, a drastic decrease in tea quality is observed (Mwakha, 1990; Owuor *et al.*, 1991; Owuor & Odhiambo, 1993).

The origin of Turkish tea is Georgian tea, which is a hybrid carrying much Chinese tea character. The quality and yield in Turkish tea plantations are low because the tea was grown from seed. As a consequence, the content of TF in black tea produced in Turkey has been reported to be between 0.17 and 5.04 mol g^{-1} (Oksüz & Kayíkcí, 1993; Tüfekci, 1992), which is lower than in Indian, Kenyan, Argentinean and Malawi tea with TF values of 25–27.5, 7.1–33.3, 8.5–20.5 and 6.3–28.6 mol g^{-1}, respectively (Owuor *et al.*, 1986; Malec & Vigo, 1988; Cloughley, 1980; Ellis & Cloughley, 1981). Clones with higher TF values and specifically developed for the conditions obtaining in Turkey will have to be brought into production. This paper has used the TF value as the sole criterion of quality, but it must be appreciated that this is only a crude approximation.

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REFERENCES

Abdul-Gaffar, N. M., Kandappah, C. S., Alawattegama, T. & Samarasingham, S. (1980). Effect of period of fermentation on the liquoring characteristics of made tea. *Tea Q.*, **49**, 58–64.

Cloughley, J. B. (1979). The determination of optimum fermentation in the factory. In-line theaflavin analysis during fermentation. *Q. Newsl.*, **55**, 16–18.
Cloughley, J. B. (1980). The effect of fermentation temperature on the quality parameters and price evaluation of Central African black teas. *J. Sci. Food Agric.*, **31**, 911–919.
Davies, A. G. (1983). Theaflavins objective indicators of quality. *Tea Coffee Trade J.*, **155**, 34.
Ellis, R. T. & Cloughley, J. B. (1981). The importance of theaflavin in tea liquors. *Int. Tea J.*, **2**, 7–8.
Hilton, P. J. (1973). Tea. In *Encyclopedia of Industrial Chemical Analysis*, Vol. 18, eds F. D. Snell & L. S. Ettre. Wiley, New York, pp. 455–516.
Hilton, P. J. & Ellis, R. T. (1972). Estimation of the market value of Central African teas by theaflavins analysis. *J. Sci. Food Agric.*, **23**, 227–232.
Hilton, P. J. & Palmer-Jones, R. W. (1973). Relationship between the flavanol composition of fresh tea shoots and the theaflavin content of manufactured tea. *J. Sci. Food Agric.*, **24**, 813–818.
Hilton, P. J. & Palmer-Jones, R. W. (1975). Chemical assessment of quality in tea and its relation to the market over an extended period. *J. Sci. Food Agric.*, **26**, 1681–1687.
Malec, L. S. & Vigo, M. S. (1988). Seasonal variation in theaflavin, thearubigin and caffeine content of Argentinian black teas. *J. Sci. Food Agric.*, **45**, 185–190.
McDowell, I., Feakes, J. & Gay, C. (1991). Phenolic composition of black tea liquors as a means predicting price and country of origin. *J. Sci. Food Agric.*, **55**, 627–641.
Mwakha, E. (1990). Response of seedling tea to height and frequency of mechanical harvesting in Kenya Highlands. *Tea*, **11**, 6–13.
Oksüz, M. & Kayíkcí, A. C. (1993). Quality characteristics of black tea manufactured in Turkey. An Annual Report. Directory of Tea Processing Plants, Rize, Turkey.
Owuor, P. O. (1982). Can theaflavins contents alone be adequate parameter in black tea quality estimation? *Tea*, **3**, 26–40.
Owuor, P. O. (1987). The evaluation of photometric methods and organoleptic assessment for optimising fermentation during black tea manufacture. *Tea*, **8**, 21–26.
Owuor, P. O. & Odhiambo, H. O. (1993). The response of quality and yield of black tea of two *Camellia sinensis* varieties to methods and intervals of harvesting. *J. Sci. Food Agric.*, **62**, 337–343.
Owuor, P. O. & Reeves, S. G. (1986). Optimising fermentation time in black tea manufacture. *Food Chem.*, **21**, 195–203.
Owuor, P. O., Wanyoko, J. K. & Reeves, S. G. (1986). Correlation of theaflavins content and valuation of Kenyan black teas. *J. Sci. Food Agric.*, **37**, 507–513.
Owuor, P. O., Obanda, A. M., Tsushida, T., Horita, H. & Murai, T. (1987). Geographical variation of theaflavins, thearubigins and caffeine in Kenyan clonal black teas. *Food Chem.*, **26**, 223–230.
Owuor, P. O., Othieno, C. O. & Reeves, S. G. (1987). The Kenyan position on theaflavin in tea. *J. Food Agric.*, **1**, 185–186.
Owuor, P. O., Othieno, C. O., Robinson, J. M. & Baker, D. M. (1991). Changes in the quality parameters of seedling tea due to height and frequency of mechanical harvesting. *J. Sci. Food Agric.*, **55**, 241–249.
Owuor, O., Orchard, J. E. & McDowell, I. J. (1994). Changes in the quality parameters of clonal black tea due to fermentation time. *J. Sci. Food Agric.*, **64**, 319–326.
Philip, O. O. & Reeves, S. G. (1986). Optimising fermentation time in black tea manufacture. *Food Chem.*, **21**, 195–203.
Reeves, S. G., Gone, F. & Owuor, P. O. (1985). Theaflavin analysis of black tea problems and prospects. *Food Chem.*, **18**, 199–210.
Roberts, E. A. H. (1958). The chemistry of tea manufacture. *J. Sci. Food Agric.*, **9**, 381–390.
Roberts, E. A. H. (1958). The estimation of theaflavins in tea. *Two and A Bud*, **5**, 11–12.
Roberts, G. R. & Chandradasa, P. B. (1982). A simplified method of rapid measurment of the degree of fermentation during tea manufacture. *Tea Q.*, **51**, 62–71.
Schallies, M., Morgil, I., Yilmaz, A. & Secken, N. (1994). Bestimmung des Schadstoffgehaltes von Türkischem Tee. *Chim. Acta Turc.*, **22**, 415–420.
Tüfekci, M. (1992). Turkish black tea quality. *Standard*, **363**, 109–113.
Thanaraj, S. N. S. & Seshadri, R. (1990). Influence of polyphenol oxidase activity and polyphenol content of tea shoot on quality of black tea. *J. Sci. Food Agric.*, **51**, 57–79.
Vanlý, H., Bilsel, M., & Sarýmehmet, M. (1987). Evaluation of different methods for Turkish black tea manufacture. International Tea Symposium, 26–28 June, Rize, Turkey, p. 169.
Werkhoven, J. (1974). Tea processing. FAO Agricultural Services Bulletin, Report No. 26. Food and Agricultural Organization of the United Nations, Rome, Italy.