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Optimization Of High Pressure Rotorvane For Quality In Orthodox Tea Processing

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***Abstract* - Orthodox processed tea refers to loose large whole particle tea leaf produced using traditional (or orthodox) methods of tea production, which involve plucking, withering, maceration/rolling, oxidation/fermentation and drying. Current orthodox tea technologies produce teas of very low quality but have large loose-leaf particle teas preferred by Orthodox tea consumers. Conventional black tea process includes CTC (Cutting, Tearing and Curling) which replaces the rolling stage in the Orthodox tea processing. The CTC tea manufacturing process produces high quality teas but is dusty making the tea undesirable to some consumers. high pressure Rotorvane has been designed for processing of Orthodox teas *[1]* by converting standard Rotorvane from Low to high Pressure expected to produce Orthodox Large Particle Tea that is able to infuse like normal conventional black CTC teas. To optimize the fabricated high Pressure Rotorvane, experimental method of research was used to conduct the studies. Factory trials were done using 15'' Rotorvane at different pressures and were then tracked through the innovation manufacturing process. Made tea samples for each trial were drawn and assessed by tea tasters for quality using the Unilever International Tea Categorisation System (ITCS) and quality comparisons made. It was found out that the higher the Rotorvane pressure the higher the quality of made tea for the Large Particle Teas from the Rotorvane process to an optimum level of 25MN/m^2 producing large leaf teas that looks and feels like orthodox tea but has the liquor characteristics matching CTC made tea quality on Taste, Colour and Mouthfeel. Leaf score remained lower than CTC teas due to the Large Particle leaf appearance.**

***Keywords* – Rotorvane; Orthodox Tea; CTC; Black Tea; Maceration**

I. INTRODUCTION

The conventional CTC black tea process involves withering finely plucked leaf from 78% moisture content to 70 ±2% moisture content [2]. The withered leaf is passed through a standard Rotorvane at a pressure of about 5MN/m^2 [2]. The macerated leaf (ex-Rotorvane) is passed through a triplex CTC, fermented for 2 hours before drying and sorting into various grades [2].

The black tea process flow chart is as shown below:

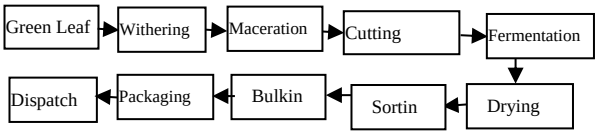

Fig. 1: Black Tea Manufacturing Process [2], [1]

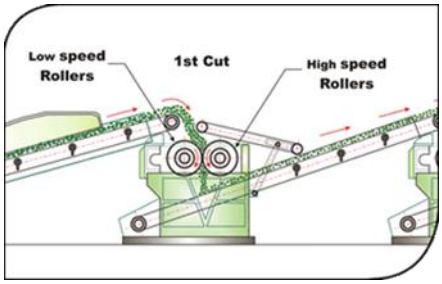

Fig. 2: CTC process [2], [1]

CTC (cutting, tearing and curling), at the cutting stage, in conventional black tea process opens up catechins in plant cells in leaves that later oxidises in the fermentation stage thus producing high quality teas with good attribute of taste (flavour), hue/colour and mouthfeel when infused [3]. CTC teas are dusty making the tea undesirable to Orthodox tea consumers who prefer large whole leaf particle teas [4]. However, current orthodox tea technologies produce teas of low quality because the process releases less catechins in plant cells during the rolling process.

The aim of this research paper is to optimize designed high pressure Rotorvane [1] for Orthodox tea processing by subjecting the withered leaf to a high pressure above conventional manufacturing pressure of 5 MN/m2 to rapture leave plant cells so as to release the catechins for the fermentation process thus eliminating CTC process while producing orthodox large particle teas that looks and feels like orthodox large leaf tea and has the liquor characteristics matching CTC tea quality when infused.

Fig. 3: CTC and Orthodox tea images [4], [1]

II. MATERIALS AND METHODS

A. Equipment and Experiments Set up

This research experiments were conducted using 15"high Pressure full-scale factory Rotorvane as designed [1], fabricated and after dry run of all the components.

Rotorvane barrel wall (on the inside) was fitted with a pressure sensor. As the Rotorvane vanes press leaf against the resistors (bolted onto the Rotorvane barrel), the sensors pick up the pressure (stress) signal which is converted to a digital electronic form and displayed in the data logger screen every minute. The electronic data logger displays readings in Pascal (Pa, N/m^2). (fig. 4).

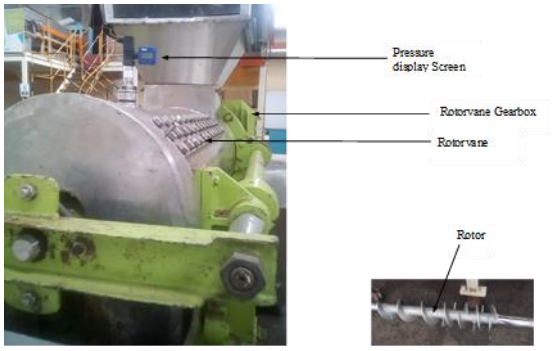

Fig 4: Rotorvane fitted with pressure gauge [1], [2]

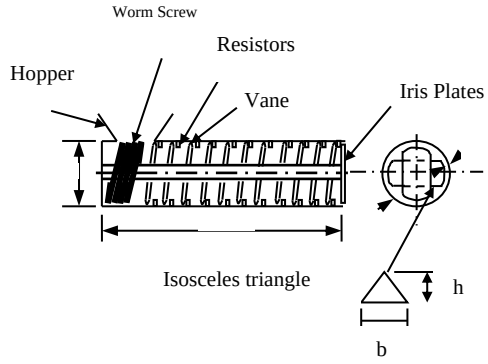

Fig. 5a: Rotorvane Sketches [1], [2]

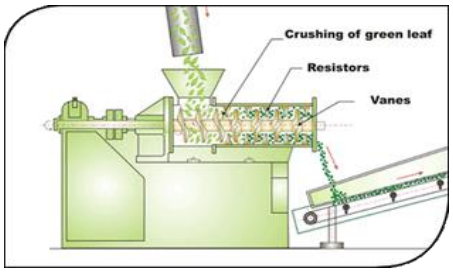

Fig. 5b: Rotorvane Sketches [1], [2]

Leaf at normal manufacturing plucking standards of 65% acceptable were withered to 70±2% Moisture Content [5] and passed through the high pressure Rotorvane set to 5 cm iris opening at the following different throughputs (different pressures):

i) 1000 kg/hr (at 5.5 MN/m^2 (equivalent to orthodox teas)
ii) 1100 kg/hr (at 10.2 MN/m^2)
iii) 1300 kg/hr (at 15.7 MN/m^2)
iv) 1500 kg/hr (at 20.8 MN/m^2)
v) 1750 kg/hr (at 25.1 MN/m^2)

Rotorvane pressures for each trial were measured and monitored. The data logger was set to record an average figure every 4 minutes. The trials ran for 1 hour at the Rotorvane.

Similar leaf is also passed through a standard Rotorvane and triplex CTC at 1000 kg/hr of withered leaf for comparison, as a control experiment for standard quality comparison.

The leaf was tracked through the manufacturing process. 5 repeats for each set were done. Samples for grades Large Leaf (LL) and Medium Leaf (ML). Grade Pekoe Fannings1 (PF1) for control) trial were also picked. All samples were sent to a panel of tea tasters for made tea quality assessment using the Unilever International Tea Categorisation System (ITCS).

The research was conducted at Unilever Tea Kenya Limited Kericho in conjunction with Multimedia University of Kenya, Department of Mechanical and Mechatronics Engineering. All the materials were sourced from the local markets.

*B. Tea Tasting Scoring Method **[5]***

The standard Tea Taster's methodology for the Unilever International Tea Categorisation System (ITCS) is 5.6 grams of tea in 280 ml of water. The same is applicable to the innovation process. The taste batch preparation methodology for its prime grades, Large Leaf (LL) and Medium Leaf (ML), is prepared through the following stages:

•5.6 grams of tea placed in a tasting mug

•280 ml of freshly boiled de-ionised water is added to the tea

•Brew is timed for 6 minutes

•The liquor is tipped into the tasting bowl

•The tea is tasted black with no additions for LYL blend

With grades to be assessed for the European Market, the preparation methodology is the same except that milk (preferably 5 cc of semi skimmed milk) is added to the bowl before the liquor is tipped. The liquor assessment is made using the International Tea Categorisation System and a brief description is given as a guide. There are four attributes that have to be scored. Taste and Mouthfeel that relate to taste and Colour and Brightness that are visual attributes.

The tea characteristics are scored on a scale, 0.6 score being the lowest and 9.4 score being the highest and moves up / down in steps of 0.2 score. 5.0 score is the mid-point and is where LYL423 (Lipton Yellow Label) blend is rated for each attribute. A brief description is given in table 2.3 below to help interpretation:

Table I: ITCS tea tasting and scoring scale [5]

Without milk

Taste	0.6	----------	9.4
	plain coarse		lively astringent character
Colour/Hue	0.6	----------	9.4
	clear pale		deep and dark
Mouthfeel	0.6	----------	9.4
	Thin watery		viscous heavy and mouth coating

With milk

Taste	0.6	----------	9.4
	plain coarse		lively astringent character
Colour	0.6		9.4
	pale yellowy green		deep dark red
Mouthfeel	0.6	----------	9.4
	thin watery		thick and viscous Mouthfeel
Leaf	1	----------	5
	Open/Flat/Fibrous		Round/Black / Appealing

Reference teas of known characteristics need to be liquored at the front of any batch as a benchmark, only then can accurate assessments be made for Taste, Colour, Brightness and Mouthfeel. There are a range of reference standard blends that can be used and their ITCS characteristics are as follows:

Table II. ITCS tea tasting standard reference samples [5]

T C B ML
LYL 4235.05.05.05.05
LYL 5055.04.45.04.45
LYL 6405.04.05.04.05
PG TB4.85.05.24.85
Orthodox3.62.84.04.02

Large Leaf (LL) or Medium Leaf (ML) recently scored by the tea buyers or Unilever Tea Kenya Sales and Marketing department can be used as reference tea.

III. RESULTS AND DISCUSSIONS

A. Tea Tasting Results and Discussion (Factory Trials)

The tea tasters tasted made tea samples from each set of performance and optimization trials. Tasting results (appendix 5) for Large Leaf (LL) and Medium Leaf (ML) grades on Taste (T), Hue / Colour(C), and Mouthfeel (M) and Leaf (L) are summarised graphically as shown below:

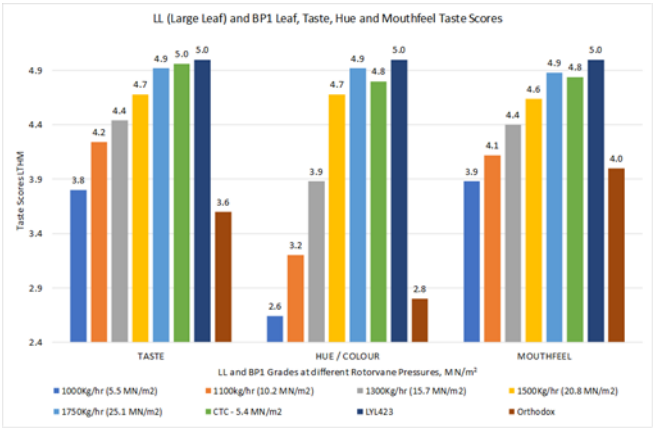

Fig. 6: Large Leaf (LL) and Broken Pekoe1 Taste, Hue and Mouthfeel Scores

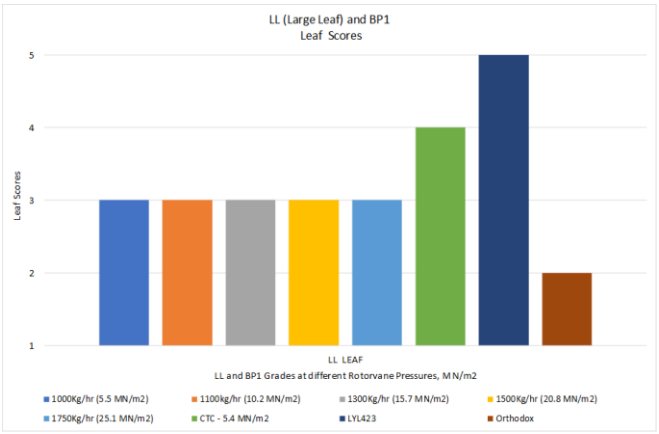

Fig. 7: Large Leaf (LL) and Broken Pekoe1 Leaf Scores

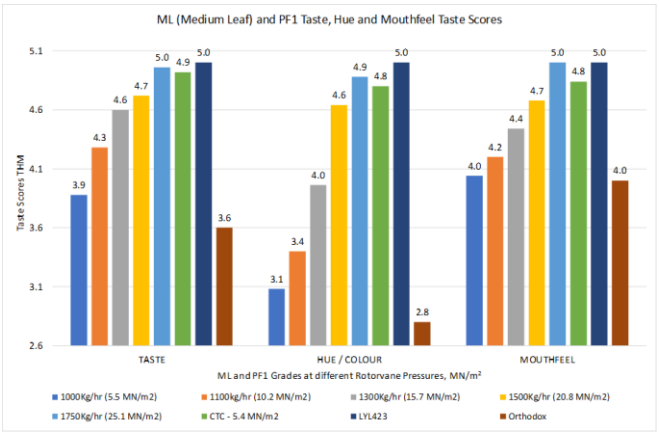

Fig. 8: Medium Leaf (ML) and Pekoe Fannings1 Taste, Hue and Mouthfeel Scores

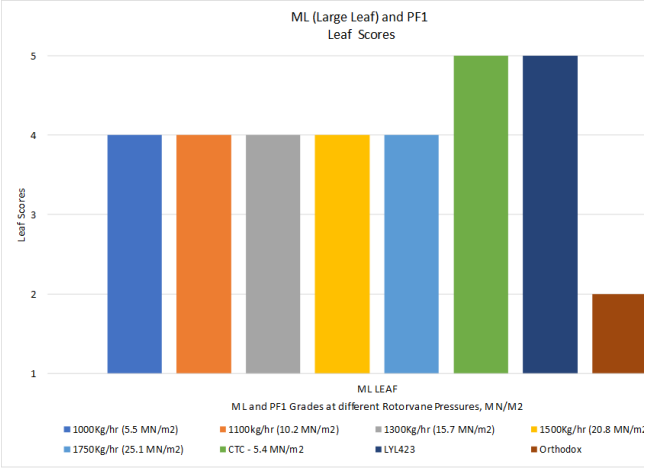

Fig. 9: Medium Leaf (ML) and Pekoe Fannings1 Leaf Scores

CTC black tea | Existing Orthodox Teas | Orthodox tea from research

Fig. 10: Trial Samples leaf appearance compared to CTC and existing orthodox teas

Orthodox | RV – 10.2MN/m^2 | CTC | RV – 20.8 MN/m^2 | RV – 25.1 MN/m^2 | LYL423

Fig. 11: CTC and Orthodox Tea Quality (without milk)

Orthodox | RV – 10.2MN/m^2 | LYL423 | CTC | RV – 25.1 MN/m^2

Fig. 4.10 CTC and Orthodox Tea Quality (with milk)

From the high pressure Rotorvane factory trials the following were observed:

i) There was no impact in the rest of the manufacturing processes (withering, drying, sorting, etc.) on the various Rotorvane throughputs.

ii) Pressure was increased at an average of 4.9 MN/m^2 for each set of trials.

iii) For Large Leaf (LL) grade:

- Taste improves from 3.8 score at 5.5 MN/m^2 to 4.9 score at 25.1 MN/m^2. There was an improvement of an average 0.3 score in every step. This is against CTC standard of 5.0 score and Orthodox conventional score of 3.6.
- Colour improves from 2.6 score at 5.5 MN/m^2 to 4.9 score at 25.1 MN/m^2. There was an improvement of an average of 0.6 score in every step. This is against CTC standard of 5.0 score and Orthodox conventional score of 2.8.
- Mouthfeel improves from 3.9 score at 5.5 MN/m^2 to 4.9 score at 25.1 MN/m^2. There was an improvement of an average of 0.3 score in every step. This is against CTC standard of 5.0 score and Orthodox conventional score of 4.0.
- Leaf appearance has a marked improvement from conventional Orthodox score of 2 to 3 for Large Leaf (LL) grade in all pressure points (5.5 MN/m^2 to 25.1 MN/m^2). This is against CTC/LYL423 standard score of 5.0.

iv) For Medium Leaf (ML) grade:

- Taste improves from 3.9 score at 5.5 MN/m^2 to 5.0 score at 25.1 MN/m^2. There was an improvement of an average 0.3 score in every step. This is against CTC standard of 5.0 score and Orthodox conventional score of 3.6.
- Colour improves from 3.1 score at 5.5 MN/m^2 to 4.9 score at 25.1 MN/m2. There was an improvement of an average of 0.5 score in every step. This is against CTC standard of 5.0 score and Orthodox conventional score of 2.8.
- Mouthfeel improves from 3.9 score at 5.5 MN/m^2 to 4.9 score at 25.1 MN/m^2. There was an improvement of an average of 0.2 score in every step. This is against CTC / LYL423 standard of 5.0 score and Orthodox conventional score of 4.0.
- Leaf appearance has a marked improvement from conventional Orthodox score of 2 to 4 for Medium Leaf (ML) grade in all pressure points (5.5 MN/m^2 to 25.1 MN/m^2). This is against CTC standard score of 5.0.

v) Large Leaf (LL) and Medium Leaf (ML) International Tea Categorisation System (ITCS) scores at 25.1 MN/m^2 Rotorvane pressure closely matches the CTC/LYL423 made tea quality on taste, colour (hue) and mouthfeel with improved made tea leaf appearance compared to Orthodox teas. From the Factory high pressure Rotorvane trials, all Large Leaf (LL) and Medium Leaf (ML) made tea samples are within acceptable Orthodox leaf appearance requirements with improved black appearance score of 3 for Large Leaf (LL) and 4 for Medium Leaf (ML)

against the traditional fibrous grey appearance of Orthodox tea (Score 2).

vi) For the large particle teas, when compared to previous studies on Orthodox tea quality improvement;

- Quality of tea produced at 5.5 MN/m^2 were similar to those of infrared radiation process [6] and dhool addback process [7] since they were semi-fermented and produced low quality made tea with matching leaf appearance. Pressures above 5.5 MN/m^2 produced better made tea quality with every increase in pressure upto an optimum of 25.1 MN/m^2.
- Quality of tea produced at the optimum pressure of 25.1 MN/m^2 were similar to those of steam heat shock process [8], Rosalind C. H. et al (2000) Carbon dioxide impregnation process [9], though the high-pressure process is more economically viable due to less energy consumption and less process set up (process simplicity). High pressure process mouthfeel scores were significantly better than the steam heat shock process due to its lower moisture content. high pressure process tea also exhibited much better leaf appearance compared to all the previous studies.
- The high-Pressure Process tea produced better teas than the dhool addback process [7] since the addback process tea experienced particle separation after drying or in storage.

vii) From the Factory Trials, the optimum pressure for high pressure Rotorvane is 25 MN/m^2 whose Orthodox made tea which matches the CTC made tea quality on taste, colour (hue) and mouthfeel with improved made tea leaf appearance compared to conventional / existing Orthodox teas. Beyond 25 MN/m^2 the Rotorvane chokes often and leaf flow become erratic (inconsistent) with improved made tea leaf appearance compared to Orthodox teas.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

i) For Orthodox teas (Large Leaf (LL) and Medium Leaf (ML) grades), the higher the Rotorvane pressure the higher the made tea quality up to an optimum of 25 MN/m^2, which gives the highest quality on Taste (T), Colour (C) and Mouthfeel (M) scores matching CTC made tea quality, with better leaf scores compared to conventional / existing Orthodox teas and with no impact in the rest of the manufacturing processes (withering, drying, sorting, etc.).

B. Recommendation

i) From the factory trials, results, discussions and conclusions obtained, high pressure Rotorvane should be used as a standard equipment in the processing of high-quality Orthodox teas in the Tea industry.

C. Recommendation for Further Work

i) Since there is a direct correlation between pressure and made tea quality, there is need to develop and/or do further redesign and fabrications at the Rotorvane so that it can handle pressures higher than 25 MN/m2 with a smooth consistent flow. Since the Rotorvane may be limited on this, it may involve investigation on the usage of other tea maceration machines other than the Rotorvane.

ii) The impact of Rotorvane pressure on CTC made tea quality was not investigated and may be beneficial. This needs to be done to check impact and possibility of further improving made tea quality for CTC black tea.

ACKNOWLEDGMENT

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