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Optimisation and validation of high-temperature oxidation of *Cyclopia intermedia* (honeybush) – From laboratory to factory

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ABSTRACT

Inconsistent and poor quality honeybush herbal tea, produced from *Cyclopia intermedia*, required that comprehensive sensory profiling of this *Cyclopia* species be undertaken to identify not only its characteristic sensory attributes, but also to identify negative attributes, including taints responsible for poor quality. This was achieved by descriptive sensory analysis of infusions, prepared at "cup-of-tea" strength of a large sample set sourced from processors and retail outlets. The aroma attributes, "fynbos-floral", "fynbos-sweet" and "woody", and to a lesser extent, "fruity-sweet" and "apricot jam", were the most prominent. The presence of taints such as "smokey" and "wet fur/farm animals" at relative high intensities in some samples indicated poor processing practices. The presence of "green grass" and "dusty" aroma notes is most likely attributable to under- and over-fermentation, respectively. Fermentation is the high-temperature oxidation step essential for the development of the characteristic sensory attributes of traditional honeybush tea. High turbidity levels of some infusions further confirmed sub-optimal processing of plant material. The effects of fermentation temperature (70, 80 and 90 °C) and time (12, 16, 24, 36, 48, and 60 h) on the sensory characteristics of *C. intermedia* infusions were thus investigated on laboratory-scale to establish optimum conditions. Different fermentation temperatures produced teas with slightly different sensory profiles, with infusions of plant material fermented at 70 °C predominantly floral, at 80 °C predominantly fruity and at 90 °C overall most characteristic of *C. intermedia.* Fermentation at 90 °C for 24 h or 36 h proved effective to increase the major positive aroma attributes to prominent levels, while decreasing the negative aroma attributes to negligible levels. These conditions were thereafter validated on factory-scale. Fermentation performed concurrently on the same batches of plant material on laboratory- and factory-scale delivered more or less the same product in terms of aroma profile and "cup-of-tea" strength, with the latter assessed according to the soluble solids content, colour and turbidity of the infusion. For optimum quality, inherent batch-to-batch variation in plant material may require careful monitoring of aroma development during fermentation between 24 and 36 h. Application of the optimum fermentation temperature-time combination by industry will contribute towards improved and consistent product quality.

1. Introduction

Globally consumers are increasingly health-conscious, leading to greater appreciation for natural products, including herbal teas. As a result, the market for honeybush tea, produced from a number of *Cyclopia* species, has seen rapid growth since its "re-discovery" in the early 1990s. Demand is currently exceeding supply (Joubert et al., 2011), necessitating that each production batch should meet optimum quality standards. With the transition from a cottage industry to a formalised industry supplying mainly an export market, attention was given to improve inconsistent and poor product quality. Du Toit and Joubert (1999) investigated the high-temperature oxidation ("fermentation") step of *C. intermedia* as this species provided the bulk of production at that stage, and which is still currently the case. Optimum quality was defined by the development of a sweet-associated flavour, obtained when *C. intermedia* was fermented at 70 °C/60 h or 90 °C/36 h. At that stage no attempt was made to further characterise this positive broad-based sensory attribute and to identify negative attributes. Given the long fermentation period, especially at 70 °C, some processors have chosen not to adhere to the recommended conditions, choosing instead to use lower temperatures or shorter times in an attempt to either increase throughput, save energy or accommodate limitations of processing equipment. Erasmus et al. (2016), investigating the fermentation of

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C. genistoides, *C. subternata*, *C. maculata* and *C. longifolia*, and using the high temperature-short time regime applied by some processors (Joubert et al., 2011) as starting point, demonstrated that a good quality herbal tea could be obtained at 80 °C/24 h or 90 °C/16 h, depending on the specific species and aroma profile required. Given the possibility that a high temperature/short time fermentation regime could be suitable for producing a good quality herbal tea from *C. intermedia*, in addition to the progress we have made to date to characterise the evolution of the aroma profile of a number of *Cyclopia* species during fermentation (Theron et al., 2014; Erasmus et al., 2016), the present study revisited the optimisation of the fermentation conditions of *C. intermedia*.

The aim of the present study was to confirm 70 °C/60 h or 90 °C/36 h as optimum fermentation conditions or to establish a new set of optimum conditions for *C. intermedia*. A large number of commercial production samples of *C. intermedia* were collected from processors and retail outlets in an attempt to fully define its sensory profile and determine the extent of variation in quality. Following determination of the optimum fermentation temperature–time combination(s) for *C. intermedia* on laboratory-scale, validation of these combinations was carried out on factory-scale.

2. Materials and methods

2.1. Commercial C. intermedia samples

A total of 54 production batches of fermented *C. intermedia* were sourced from commercial processors, farm stalls and supermarkets throughout the Western and Eastern Cape provinces of South Africa. The sample set served to capture sensory variation in terms of attributes and intensities, particularly to identify the major aroma attributes associated with *C. intermedia*. Another aim was to gain insight into the presence of negative attributes and taints that could point to sub-optimal fermentation conditions. The samples were stored at room temperature in glass jars until analysis.

2.2. Optimisation of fermentation conditions on laboratory-scale

Three batches of *C. intermedia* plant material (30 kg/batch), with each batch representing an independent replicate, were harvested at different times over a period of 6 weeks (June–July) from two commercial plantations on a farm near Barrydale (Western Cape) and a natural stand on a farm in the Langkloof (Eastern Cape), respectively. Shoots of several plants were harvested and pooled to form a batch. Thick stems, largely devoid of thin side branches with leaves, were removed before processing. The plant material was mechanically shredded (ca 3 mm), moistened to ca 60% moisture content and mixed thoroughly before sub-division ($n = 18$; 1.5 kg/sub-batch). Each sub-batch was placed in a stainless steel container (140 × 200 × 180 mm where 140 mm is the depth) and covered with a double layer of heavy duty aluminium foil to prevent excessive moisture loss during fermentation (Fig. 1). The sub-batches ($n = 3 \times 6$) were randomly allocated to three pre-heated laboratory ovens at 70, 80 and 90 °C, respectively. One sub-batch was removed from each oven after predetermined time intervals (12, 16, 24, 36, 48 and 60 h) and the fermented plant material spread out on four drying trays (395 mm × 565 mm; 30 mesh; 4 trays/sub-batch). The trays were placed in a cross-flow temperature-controlled dehydration tunnel (Continental Fan Works, Parow, South Africa) at 40 °C for 6 h to dry the fermented plant material to ca 10% moisture content. Each dry sub-batch was mechanically sieved as described by Theron et al. (2014) and the "tea bag" fraction (<12 mesh; >40 mesh) was collected and stored at room temperature in sealed glass jars until analysis.

2.3. Validation of optimum fermentation conditions on factory-scale

Four batches of *C. intermedia* (330–666 kg/batch), representing replicates, were harvested over a period of 10 days from natural stands at locations near the factory, situated in the Langkloof. The individual batches were mechanically shredded (<5 mm) and deposited directly into steam-heated, double-walled stainless steel fermentation tanks (Fig. 1). Each tank has a capacity of 500 kg plant material and is equipped with rotating paddles to ensure adequate mixing and heat transfer during fermentation. A steam injector was used to rapidly increase the temperature of the plant material to ca 90 °C. The plant material had a high inherent moisture content (ca 60%) and required only superficial wetting to aid the fermentation process. Samples were collected after 16, 24, 36 and 48 h, spread out on drying trays (370 mm × 310 mm; 50 mesh; 4 trays/sample) and dried in a cross-flow dehydration tunnel at 40 °C for 6 h to less than 10% moisture content.

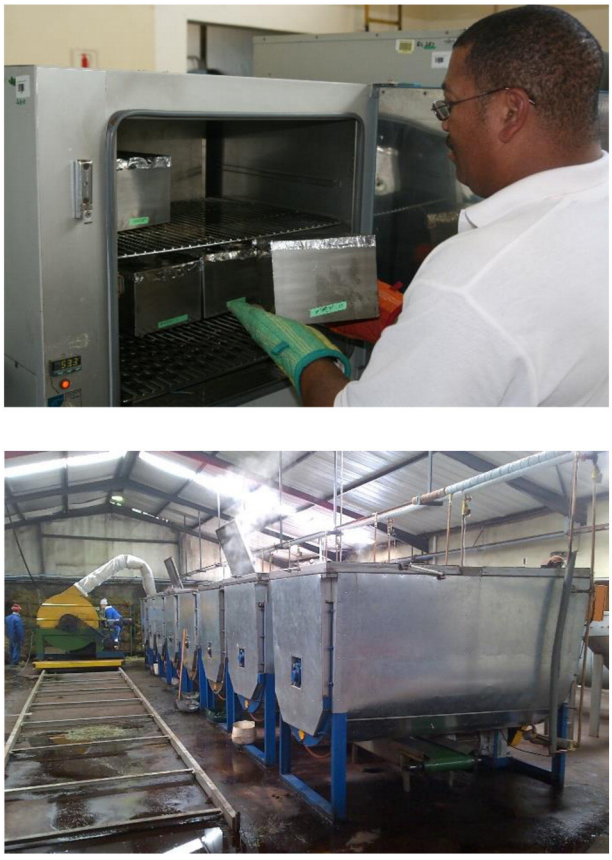

Fig. 1. Laboratory-scale fermentation in stainless steel containers (capacity 1.5 kg/unit) placed in a laboratory oven (top) vs factory-scale fermentation in a battery of double-walled stainless steel fermentation tanks (capacity of 500 kg/unit) (bottom).

Laboratory-scale fermentation, as described for the previous experiment (Section 2.2), was executed concurrently on the same plant material batches to allow direct comparison. As soon as the bulk plant material was shredded and mixed, four samples per batch (ca 1.5 kg/sample) were collected, superficially wetted as for the bulk plant material and fermented in stainless steel containers in a laboratory oven at 90 °C (Fig. 1). The samples were removed after 16, 24, 36, and 48 h and dried as described for the factory-scale samples. All dried samples were mechanically sieved, their "tea bag" fraction collected (as described in Section 2.2) and stored in sealed glass jars until analysis.

2.4. Descriptive sensory analysis

Infusions were prepared by pouring 1 L freshly boiled distilled water on 12.5 g tea leaves in a glass jug to infuse for 5 min, whereafter it was decanted through a tea strainer into a 1 L preheated stainless steel thermos flask (Woolworths, South Africa). Approximately 100 mL of each

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