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Influence of post harvest processing conditions on yield and quality of Curcuma longa (L.) ground rhizomes produced in Benin

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ABSTRACT

Studies were carried out to evaluate the effect of post harvest processing conditions on yield and quality of Curcuma longa (L.) rhizomes infusettes. A material balance was determined for four production processes including or not peeling and blanching. Sliced and dried rhizomes were packaged on tea bags and the products quality was monitored using reference methods. Production yields ranged from 38.39 to 76.87% with higher values obtained from unpeeled and blanched rhizomes. The moisture content varyed from 3.15 to 3.75 % m/m with a significant difference ($P< 0.05$) between the peeled and blanched samples which got lower values compared to the others. Microbiological analyses revealed that all samples were of satisfactory quality. Phytochemical screening showed that the presence or absence of metabolites was not influenced by these processing conditions. Peel removal caused mass loss of 33% without blanching but the tea bags obtained from this process had higher intensity of yellow-orange color. Peeling, blanching and drying were operations that affect not only the yield but also the quality of Curcuma longa (L.) rhizomes infusettes.

Introduction

Over the centuries, the different healing properties of plants have been exploited by humans. Traditional medicine still occupies an important place in the treatment of various diseases and is of increasing health and economic importance. Indeed, 80% of the African population and 40% of the Chinese population use traditional medicine for primary health care (WHO 2018). In Benin, the diseases treated include common diseases (malaria, hepatitis, etc.) but also more serious diseases related or not to oxidative stress (diabetes, high blood pressure, cancer, HIV-AIDS, etc.). Oxidative stress-related diseases and cancers are on the rise worldwide, particularly in Benin. In 2018, WHO reported 18.1 million new cases and 9.6 million deaths due to cancer. In Benin, the prevalence of cancer-related deaths is 3.8% (WHO 2014), while 8,000 new cases and 6,000 deaths are recorded each year (Lawson 2020). In view of the seriousness of this pathology, the very low income of the beninese population, the means of treatment almost non-existent and their high costs, it is necessary to adopt preventive measures at a lower cost. One of the preventive measures to promote is the integration into our eating habits of plants with high antioxidant activity such as Curcuma. Indeed, Curcuma longa L. (Zingiberaceae), is the most known species of the genus Curcuma met most often in tropical Asia, Asia-Pacific, South Pacific in India, Myanmar, Thailand, Korea, China, Australia and tropical regions (Ravindran et al. 2007). Traditionally C. longa rhizome powder is used as a food spice and dye for the food and textile industries. It is also widely used in traditional medicine, due to its therapeutic properties and safety. Indeed, various pharmacological studies have proven the many therapeutic properties of Curcuma longa and the curcuminoids it contains. Of these many properties, it can retain their anticancer properties (Tomeh et al. 2019), antiinflammatory (Lee et al. 2020) and antiarthritic (Mathai et al. 2018), related to very low toxicity. Their antimicrobial properties (Ikpeama et al. 2014), gastro-protective (Yashavanth et al. 2018), anti-aging (Savina 2014) and numerous pathologies have been reported (Ravindran et al. 2007). Also their powerful antioxidant, anti-mutagenic, anticoagulant, antidiabetic and antiviral activity were noted in the work of Ashraf and Sultan (2017). The rhizome of C. longa is marketed as a powder after three stages of blanching, drying and sieving (FAO 2004; Ravindran et al. 2007). The first two unit operations are heat treatments that could condition the quality of the finished product. Indeed, they could lead to a decrease in yield but also to the obtaining of a finished product of lower quality (Badoussi et al. 2015). In view of developing technology processing in order to obtain products of added value and good quality, this study was undertaken to assess the effect of the main unit operations carried out during the transformation of the rhizomes on the yield and quality of Curcuma longa infusettes.

1. Materials and Methods

1.1. Collection of samples

The plant material used in this study consists of the rhizomes of Curcuma longa (L). Mature fresh rhizomes were purchased from international market of Cotonou (Dantokpa market) in South of Benin. A representative sample was obtained by merging samples purchased at four different points of sale. Immediately after harvest, the rhizomes were transported to the Laboratory of Study and Research in Food Microbiology in Food Engineering Technology Department

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of Polytechnic School of Abomey-Calavi University (UAC) for processing and analysis.

1.2. Methods

1.2.1. Processing of rhizomes on infusettes

The processing of rhizomes on infusettes was carried out using the revised method of Ikpeama et al. (2014), according to the occurrence or not of the peeling or blanching. The harvested rhizomes were carefully sorted and washed with clean water to remove sand and other particles. After sorting and washing the rhizomes were divided into two lots of 2 kg each, a lot of unpeeled rhizomes and a lot of peeled rhizomes. Each of the two (02) lots obtained was subdivided into two (02) smaller lots of 1 kg and each one being submitted to a different processing condition. The first smaller lot of the peeled and unpeeled rhizomes was blanched at 80-90°C for 03 minutes, while the second smaller two lots were not blanched. The four smaller lots were then drained separately at 25°C for 5 minutes on the lab palliasse and sliced using a 02 mm diameter grater. All of the smaller lots were later dried in a Memmert brand oven at a temperature of 65 oC for 48 hours. The sliced and dried rhizomes were packaged in tea bags for analysis. At the end, four technologies of infusettes production were obtained: infusettes of unpeeled rhizomes (P1), infusettes of peeled and blanched rhizomes (P2), infusettes of unpeeled and blanched rhizomes (P3), and infusettes of unpeeled rhizomes (P4). In order to obtain reliable and reproducible results, the production tests were carried out in triplicate.

1.2.2. Material balance and production yields

The instantaneous yield (Ri) and production yield (Rp) of each unit operation were calculated using the following the method of Badoussi et al. (2015):

$$\mathbf{R_i\,(\%)}=\frac{Mass\ of\ product\ obtened}{Mass\ of\ raw\ materiel}\times 100 \text{ and } \mathbf{R_p\,(\%)}=(Ri1\times Ri2\times \ldots\times Rin)\times 100$$

with n the number of unit operations performed for a method.

1.2.3. Determination of physico-chemical parameters

- **Determination of moisture content**

The moisture content was determined using De Knegt and Brink (1998) method: 5g of the sample was inserted into a cup and weighed. The oven was used to dry the weighted sample to constant mass at 105°C and weighed. The percentage of moisture content was calculated as:

$$Moisture\ (\%)=\frac{Moisture\ losses\ by\ mass}{Mass\ of\ original\ sample}\times 100$$

- **Determination of pH**

The pH was determined by potentiometry using a pH meter (HANNA Instruments HI98150) according to the AOAC 981.12 method (AOAC 1990). 10g of each sample was weighed, grinded and suspended in 90 ml of distilled water for 30 min. The mixture obtained was filtered using a whatman paper N°1. 10 ml of the previously obtained suspension was taken to measure pH.

- **Determination of titrable acidity**

Titrable acidity was determined by titration using the AOAC method (1990). To 10 ml of the suspension previously obtained were added 2 drops of phenolphthalein. The mixture was dosed with 0,1 N sodium hydroxide solution until the turn to pale pink. The total acidity expressed in milliequivalents per 100 g of sample (meq/100g) was calculated using the formula:

$$Titrable\ acidity\ (\mathbf{meq/100g})=\frac{\mathbf{Normality\ of\ the\ sample\ solution}}{mass\ of\ the\ sample}\times 100000$$

- **Determination of total soluble dry matter**

The determination of the total soluble dry matter was made by refractometry according to AOAC 970.59 method (AOAC 1990) using a portable ATAGO refractometer graduated from 0 to 30%. The measured value (expressed in°Brix) was readed by placing 2 to 3 drops of the suspension on the device tab. This value corresponds to the boundary between the blue and white zone observable on the tongue from the refractometer eyepiece.

1.2.4. Microbiological Analysis

Samples were serially diluted with sterile 0.1% peptone water and plated into microbiological media by the pour plate technique (AOAC, 1984). To 25 g of each sample, 225 ml of peptone water was added and homogenized. From the initial concentration, appropriate decimal dilutions were prepared and aliquots were plated in duplicates on various media (ISO 6887-1: 2017). Plate Count Agar (PCA OXOID CM0463) was used for the total bacterial count. Plates were incubated at 30°C for 72 h. Desoxycholate (VRBA OXOID CM0170) was used for the total Coliforms count and plates were incubated at 30°C for 24 h. The same media was also used for the Faecal coliforms count. In this case, plates were incubated at 44°C for 24 h (ISO 4832 : 2006). Yeasts and moulds counts were determined using Sabouraud Dextrose Agar (SDA) with chloramphenicol media. 0.1 ml of initial concentration were inoculated and plates were incubated at 25 ± 2°C for 5 days (ISO 21527-2 : 2008). After incubation, the number of colonies was tracked using a colony counter. The number of bacteria expressed as Colony Forming Units per gram (CFU/g) was then determined by calculation, bearing in mind the factors of dilution (Singh et al. 1991).

1.2.5. Phytochemical analysis

Preparation of raw extracts

The raw extracts were obtained by maceration. The filtrate obtained was evaporated at 40°C using a Heidolph rotary evaporator and then dried in the oven at 40°C (Koudoro et al. 2019).

Identification of secondary metabolites

Secondary metabolites were identified by staining and precipitation reactions specific to each metabolite family (Koudoro et al. 2015).

Determination of phenolic compounds

The total phenolic compounds were determined by the Folin-Ciocalteu reagent. Total flavonoids were quantified using the aluminum trichloride method (Alcl3), while the determination of condensed tannins was done using the sulphuric vanillin method (Heimler et al. 2006).

1.2.6. Sensory analysis

The samples were infused in hot water (1g/100ml) and subjected to sensory evaluation testing using 1-3 hedonic scale (1: not pronounced; 2: not pronounced; 3: very pronounced). The mean scores of color, aroma, taste, clarity and overall acceptability of different samples were appreciated with a panel of 25 people.

1.2.7. Statistical analyses

The data generated from these studies were analysed using Statistical Program of Social Science Software (SPSS 24.0). The statistical analyses carried out were mean and standard deviation and analysis of variance (ANOVA).

The means were compared by Duncan test at 5% of probability (Gomes, 1990).

2. Results and Discussion

2.1. Main unit operations

The post harvest processing conditions of C. longa rhizomes on infusettes are shown in Figure 1. Four main unit operations were performed during the production of the infusettes. This involves peeling, blanching, grating and drying. The differences noted at the process level can be summed up in whether or not the peeling and/or blanching is carried out. These main unit operations were added regardless of the method chosen for sorting, washing, grating and drying. The production time of the infusettes was estimated for one person for all processes and for 1 kg of C. longa rhizomes per process and the unit operations performed during each production process and their duration were presented in Table 1.

Table 1. Duration (min) of unit operations per process.

Process Time (min)	P1	P2	P3	P4
Sorting	10-15	10-15	10-15	10-15
Washing	10	10	10	10
Peeling	00	60	00	60
Blanching	00	03	03	00
Slicing	60	70-75	60	60
Drying	2880	2880	2880	2880
Packaging	355-360	350	360-365	325-330
Total	3320±05	3388±05	3328±05	3340±05

Values are mean (n = 3) ± SE. The means followed by same letter in the same column are not significantly different according to ANOVA and Duncan's multiple comparison tests.

The P1 process

The P1 process consists of 5 unit operations: sorting (10-15 min), washing (10 min), grating (60 min), drying (2880 min) and packaging (355-360 min), for an average total execution time of 3320±05 min, or 55h and 25 05 min (Table 1, Figure1). The mass balance of rhizomes during processing indicated that grating caused 3% loss and 35.06% on drying (Table 2) and an overall production yield of 63±0.11%.

The P2 process

In addition to the P1 process, unit operations are peeling and blanching. Thus, the P2 process was carried out through 8 unit operations for a total execution time of 3388± 05 min, or 56h and 33±05 min on average (Table 1, Figure 1). The instant yields obtained showed material losses of 32.0% at peeling, 19.6% at drying and 14.1% at grating, material increase of 4.4% at blanching and production yield at P2 process of 48.84±0.21%. (Table 2).

P3 process

In addition to the P1 process, this process resulted in seven (07) unit operations for a total execution time of 3328±05 minutes, or 55h and 28±05 minutes on average. (Table 1, Figure 1). Losses of 23.9% during drying and 7.3% at grating, a material increase of 9% with blanching, and an overall production efficiency of 76.87±2.14% were noted (Table 2).

P4 process

The P1 process was supplemented by peeling, resulting in seven (07) unit operations for an average total execution time of 3340±05 min, or 55h and 40±05 min (Table 1, Figure 1). Losses of 37% at peeling, 23.9% on drying, 7.3% during grating, a material increase of 9% at blanching, and an overall production yield of 38.39±0.02%. % were rated (Table 2).

Figure 1. Technological diagram of curcuma longa rhizome processing on infusettes.

Each production process was dependent on the number and duration of the unit operations involved. Thus the P2 process had the longest duration while the P1 process had the shortest duration. The yield of samples on processing basis is ranged from 38,39% to 76,87% of the rhizome (Table 1). These results shown significant statistical difference ($p < 0.05$) between samples. Such a difference in yield is associated with the interference of the type of processing on

Table 2 . Instantaneous and total production yield (%) of infusettes by processing.

Instantaneous yield (%)					Total production yield (%)
Processing	**Peeling**	**Blanching**	**Slicing**	**Drying**	
P_1			97,00±0,11^a	64,94±0,04^a	63,00±0,11^a
P_2	68,00±0,11^a	104,40±0,01^a	85,91±0,51^b	80,41±0,23^b	48,84±0,21^b
P_3		109,00±0,11^b	92,66±0,11^c	76,11±2,1^c	76,87±2,14^c
P_4	67,00±0,10^b		95,52±0, 01^d	60,00±0,17^d	38,39±0,02^d

Values are mean (n = 3) ± SE. The means followed by same letter in the same column are not significantly different according to ANOVA and Duncan's multiple comparison tests.

the constituents of turmeric rhizomes which prevented the formation of small size particles during processing (Bambirra et al. 2002). The losses related to peeling (32-33%) and drying (24-35%) were more pronounced than those observed during the grating (3-7%). On the other hand, blanching induced an increase in matter (4-9%). That effect could be explained by the flash effect. According to Mafart (1994), retort cooling after pressure cooking takes place due to a drastic pressure drop and there is a fast evaporation which causes water losses by the food during depressurazion, especially when food is not packed. The loss of mass by the peeled and blanched rhizomes was higher than those of unpeeled and blanched (Table 1). This result indicates that peel protected rhizome by reducing weight losses during heat treatments. Same observation was reported by Bambirra et al. (2002) in their study on influence of post harvest processing conditions on yield and quality of ground turmeric (*Curcuma longa* L.) in Brazil. Those authors showed that removal of the peel caused 30% loss and cooking under immersion water and alkaline solution caused 3% increase in weight indicated water absorption by rhizomes during cooking. Indeed blanching is a heat treatment that was carried out to ensure the inactivation of the enzymes present in the rhizomes and that would be responsible for the adverse changes in their quality. It maintains the color, improves the texture, softens the fabrics while facilitating the drying process. It also increases the permeability of the walls and the water absorption capacity of the cells, while promoting the subsequent rehydration of the product obtained (Bambirra et al. 2002). It ensured a reduction of the drying time by 30-35%, contributed to the sterilization of the rhizomes by significantly reducing their microbial load, and reduced oxidation phenomena by eliminating air and gases. A reduced cooking time in water and at low temperature avoids the loss of turmeric pigments and soluble sugars available for the Maillard reaction and led to a very good quality powder (Ravindran et al. 2007). Low temperature drying was performed (25°C and 65°C) for reduced times (30 min and 48 hours) to provide a lightweight product that is easy to pack and store, while curbing chemical changes (Nout et al. 2003). The infusettes from the unpeeled and blanched rhizomes showed the best yield (76.9%) while the lowest yield was obtained with the peeled and blanched rhizomes (38.4%) due to the significant material losses observed during peeling, grating and drying, which highlights the influence of unit operations on production efficiency.

2.2. Influence of processing conditions on quality parameters

Curcuma longa (L.) rhizomes infusettes produced were subjected to physico-chemical, microbiological and organoleptic analyses to determine the impact of the production process on the various samples.

2.2.1. Physico-chemical characterization of Infusettes

The results of the physico-chemical analyses carried out on the various samples of infusettes produced were presented in Table 3.

The moisture content of the products obtained is ranged from 3.15% m/m to 3.75% m/m. A significantly lower yield ($p< 0.05$) was observed for peeled and blanched rhizomes compared to others. Similar reports were made by Bambirra et al. (2002), who noted that these observations were expected since peel removal caused mass loss (30%). Samples moisture content values are significantly lower than that obtained (8.53%) with samples from Nigeria (Okiki et al. 2017) and that obtained (11.36%) in France (Nasim 2016). This is due to the fact that samples used on the present study were sliced and not grounded campared to others studies. Nevertheless, values obtained were below the recommended limits for turmeric powder (10-12% m/m max.) by India, Pakistan, Uganda and Europe (BIS 2010; Pakistan Standards & Quality Control Authority 2010; ESA 2018; UNBS 2018), for a better preservation of turmeric powder. Such a behavior observed during processes were due to the occurrence or not of peeling and blanching. Gelatinized starch in the blanched rhizomes become viscoelastic and caused alteration on rheological properties making it harder to grind and sieve after deshydration (Bambirra et al. 2002). Those alterations affected also the rhizomes titrable acidity, pH and total dry matter but it did not shown significant statistical difference ($p < 0.05$) between blanched sampled which showed the lower values. Similarity were observed by Soudy (2011), whose study showed that cooking decrease significatively the acidity of the local taro variety of Chad. Indeed blanching the rhizomes prior to the dehydration process promoted geletinization of the starch, facilitating and increasing dehydration rate. It also reduces the drying time in a drying room or in the open air and should be considered as a pre-treatment for dehydration (Rivier et al. 2009), that explained the short drying time of the blanched sample.

2.2.2. Microbiological characterization of infusettes

In Table 4, the microbial enumeration in the rhizomes infusettes samples was presented. The results obtained from microbial analysis showed that they were a satisfactory microbiological quality of all samples because all the values obtained according to the bacteria and fungi parameters were below the lower limit of acceptability. This results showed that acceptable hygiene conditions were implemented during all the four processing of the infusettes production. These results also revealed the efficiency of drying during processing, which significantly reduced the microbial load of

Table 3. Physico-chemical characterization of products.

Samples	Moisture content (% m/m)	pH	Titrable acidity (meq / 100 g)	Total soluble dry matter (°Brix)
P1	$3,75\pm 0,19^{a}$	$6,70 \pm 0,02^{a}$	$92,66\pm 2,51^{a}$	$2,80\pm 0,20^{a}$
P2	$3,15 \pm 0,12^{b}$	$6,34\pm 0,02^{b}$	$70,00\pm 2,00^{b}$	$1,73\pm 0,25^{b}$
P3	$3,56 \pm 0,22^{a}$	$6,31\pm 0,01^{b}$	$70,66\pm 2,08^{b}$	$1,66\pm 0,30^{b}$
P4	$3,66 \pm 0,28^{a}$	$7,08\pm 0,02^{c}$	$72,66\pm 2,51^{b}$	$1,86\pm 0,15^{b}$

Values are mean (n = 3) ± SE. The means followed by same letter in the same column are not significantly different according to ANOVA and Duncan's multiple comparison tests.

Table 4. Microbiological characterization of infusettes.

Microbial test / Samples	Aerobie mesophilic total flora (CFU/g)	Yeasts (CFU/g)	Moulds (CFU/g)	Total coliforms (CFU/g)	Faecal coliforms (CFU/g)
P1	8.10^{3}	$< 10^{2}$	$< 10^{2}$	< 10	< 10
P2	$< 4.10^{3}$	$< 10^{2}$	$< 10^{2}$	< 10	< 10
P3	$< 4.10^{3}$	$< 10^{2}$	$< 10^{2}$	< 10	< 10
P4	$< 4.10^{3}$	$< 10^{2}$	$< 10^{2}$	< 10	< 10
OMS standard (WHO, 1999)	$< 10^{5}$	$< 10^{4}$	$< 10^{4}$	$< 10^{3}$	$< 10^{3}$
Ugandan standard (UNBS 2018)	$< 10^{5}$	$<10^{3}$	$<10^{3}$	-	-

the various samples. Similar results were found by Ahmad et al. (2016) on studies of mechanical drying influences on postharvest quality of turmeric rhizomes in Pakistan. There was no microbiological activity detected in mechanically dried samples compared to the sun dried samples of turmeric which were found contaminated with aflatoxin B 1 (Ahmad et al. 2016). Mechanical drying take less time to get require moisture level and protected from environmental hazards so end product are free from any type of contaminants such as aflatoxin (Ahmad et al. 2016). However, sample P1, which did not undergo peeling or blanching, had a higher microbial load of total mesophilic aerobic flora than the other samples. Thus, the peeling and blanching of the rhizomes had a significant influence on the microbial load of the finished product. Those results obtained are consistent with the observations of Foine (2017), which revealed that peeling reduces the risk of mould and fermentation of products. Indeed, blanching has played an antimicrobial role because of its action on the elimination of the total aerobic flora (Aboubakar 2009), while drying has contributed to the reduction of water activity, which has led to the reduction of microbial proliferation (Rivier et al. 2009). According to Colak et al., (2006), processing methods, storage conditions and postharvest treatments are responsible for the microbial contamination. The results obtained also confirmed the previous findings.

2.2.3. Sensory analysis

Mean sensory score for colour, aroma, taste, clarity and overall acceptability of various infusion samples were showed by Figure 2.

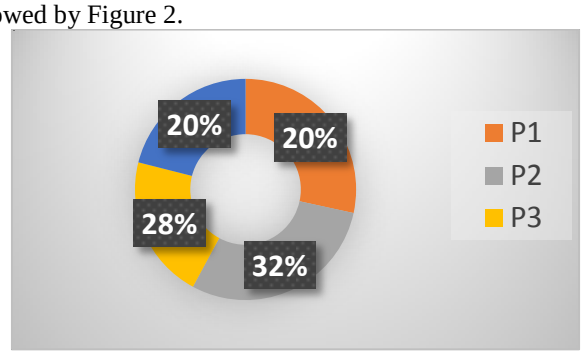

Figure 2.a. Colour assessment.

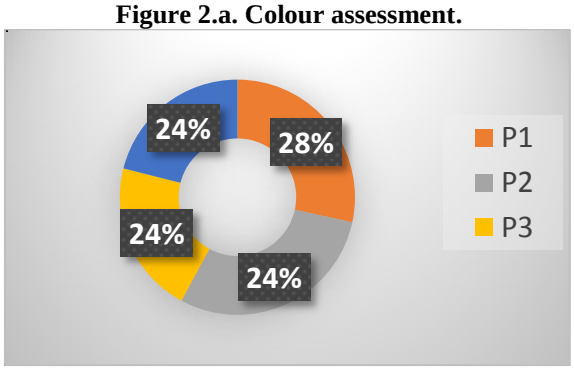

Figure 2.b. aroma assessment.

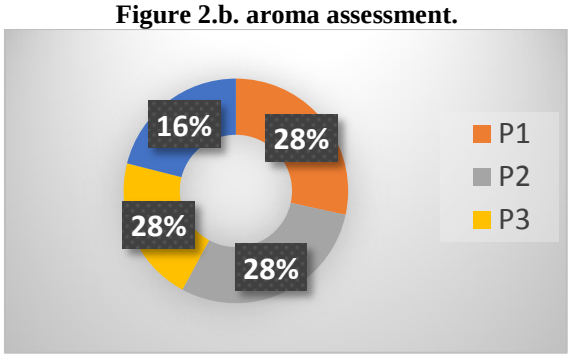

Figure 2.c. Samples taste assessment.

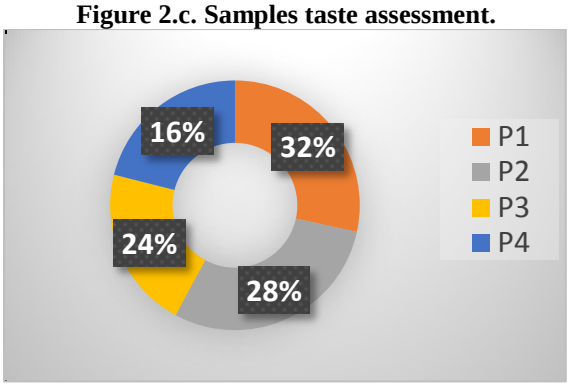

Figure 2.d. Clarity assessment.

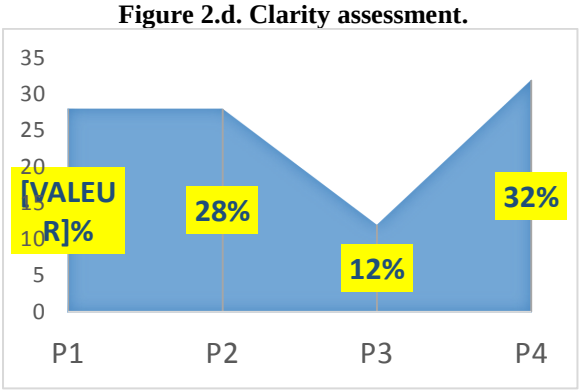

Figure 2.e. Overall acceptability assessment of the different samples.

Figure 2. Sensory Assessment.

From the analysis of Figure 2.a, it appeared that 32% of the tasters found that the infusette of P2 process has a very pronounced color. This same observation was made by 28% of tasters on the P3 process infusette. In addition, 20% of the tasters found that samples of P1 (reference sample) and P4 processes, which had not been blanched, showed a low colour. It was deduced that the blanching of the rhizomes intensifies the coloration of the infusion. This coloring was even more intense when the rhizomes were peeled and blanched, thus recalling the color of Curcuma longa (orange yellow). Similar results were obtained by Bambirra et al. (2002), who observed that the turmeric powder obtained in peeling and blanching conditions had higher intensity of yellow and red when compared to rhizome with peel. Figure 2.b showed that the aroma of all samples is very pronounced. This remark was made by 28% of tasters on the reference infusette versus 24% on the others. It can be concluded that the peeling and blanching of the rhizomes contributed to slightly reducing the aroma of the infusettes. In terms of taste (Figure 2.c), it did not appeared to be pronounced for all samples. 16% of tasters associated this observation to sample from P4 process versus 28% for others. The clarity from sample of P1 process was not pronounced according to 32% of tasters (Figure 2.d). On the other hand, the P3 process sample clarity was not very pronounced according to 24% of tasters. In addition, the samples from P2 and P4 processes showed a very pronounced clarity according to 28% and 16% of tasters respectively. Thus, the infusettes obtained from the peeled rhizomes showed better clarity compared to the unpeeled rhizomes. In addition, the P2 process sample with both peeled and blanched rhizomes showed the best score of clarity compared to other infusettes. In terms of the overall products assessment (Figure 2.e), 28% of tasters adopted samples from P1 and P2 processes compared to 12% for sample from P3 process and 32% for sample from P4 process. From all the above, it was noted that

the P4 process sample was best accepted by tasters for its slightly dark orange yellow colour, turmeric aroma, pleasant taste and rather remarkable clarity. These results were related to the peeling that would have revealed the orange-yellow colour of these samples. These results were in accordance with those of FAO (2004) and Ravindran et al. (2007), which showed that the orange-yellow colour and aromatic odour characterize the rhizomes of Curcuma longa and its derivatives. Since the samples from the P2 process were also peeled, it could be expected that these samples would be highly acceptable. Nevertheless, the colour and aroma of the final product were largely influenced by blanching. During heat treatment, the colouring matter was distributed evenly in the rhizome and then in the blanching solution followed by the evaporation of odorous principles (Ravindran et al. 2007). This observation was the basis on the best acceptability of P4 process samples compared to P2 process samples whose colour were tarnished during blanching before puting back in hot water on tasting time. Thus, processing conditions have a significant influence on the sensory quality of the final products. Post-harvest processing must therefore include peeling in order to enhance the beautiful yellow color and the characteristic aroma of the rhizomes of Curcuma longa, but also to limit the time of blanching in order to preserve the color and aroma of the infusettes, which were highly valued by tasters.

2.3. Phytochemical screening of infusettes

In Table 5, the results of the phytochemical screening of the various samples of infusettes were presented.

Table 5. Phytochemical screening

	Samples			
Parameters	**P1**	**P2**	**P3**	**P4**
Tannins	-	-	-	-
Flavenoids	+	+	+	+
Anthocyanes	+	+	+	+
Leuco-anthocyanes	+	+	+	+
Saponnins	-	-	-	-
Mucilages	+	+	+	+
Glycosides	+	+	+	+
Alkaloids	+	+	+	+
Coumarins	+	+	+	+
Cyanogenics	-	-	-	-
Anthraquinones	+	+	+	+
Quinones	+	+	+	+
+ : presence		- : absence		

The results in Table 5 showed that, in addition to alkaloids, mucilages and quinones, all of infusettes contained also phenolic compounds recognized for their various biological activities (Dossa et al. 2018). Alkaloid in tumeric plant shows that it could be used in curing headache associated with hypertension, management of cold, chronic catarrh and migraine. Tumeric plant could be necessary in the management of inflammation, improve sex hormone, lowering cholesterol, preventing deleterious and cytotoxins and could have antioxidant property as it had saponin and flavenoid (Pawar et al. 2015). Flavenoids exhibits a range of biological activities, one of which is their ability to scavenge for biological radicals and superoxide anions radicals and thus health promoting in action. Flavenoids also exhibits anti-inflammatory, antiangionic, anti-allergic effects, analgesic and antioxidant properties (Kumar and Sakhya 2013). The absence of tannins and cyanogenic compounds was noted in all samples. The absence of tannins could justify the low acidity of the samples, and the absence of astringent taste (Ikpeama et al. 2014). Similar results were obtained with ethanolic, metanolic, chloroformic and acetonic extracts of Curcuma longa rhizome powder collected in Ado-Ekiti (Nigeria) which revealed the absence of flavonoids and cyanogenic compounds in all extracts and total phenols in chloroformic extracts (Okiki et al. 2017). Abraham et al. (2018) reported the presence of flavonoids and alkaloids and the presence of tannins in the analysis of the methanolic extract of the powder of the rhizomes of Curcuma longa blanched and subjected to solar drying in Nigeria. In contrast, methanolic extracts of turmeric powder obtained from rhizomes peeled, blanched and dried at 65°C revealed the presence of tannins and cyanogenic compounds (Ikpeama et al. 2014). The differences observed could be explained by several factors such as the study method, soil type, climate, plant origin, rhizome harvesting conditions and periods. Indeed, the environment potentially influences the formation and expression of secondary metabolites (Duchêne-massias 2015). The absence of cyanogenic compounds indicates the safety of turmeric powder. In fact, these compounds are responsible for the toxicities due to the production of cyanide ions, a powerful poison with rapid action, responsible for serious disorders ranging from vomiting, nausea, vertigo and iodine deficiency to death (Cho et al. 2013). The presence of phenolic compounds in the various samples confirmed that the post harvest processing adopted in this study did not have a significant impact on the occurrence of secondary metabolites naturally present in the rhizomes of C. longa, as revealed by previous work (Colin-Henrion 2008; Viuda-Martos et al. 2012). These observations support the usefulness of turmeric plant in remedies for treatment of various infections. The presence of the same secondary metabolites in the samples from peeled rhizomes, revealed that the molecules sought are mostly found in the flesh of Curcuma longa. The yellow color of curcuma longa came from curcuminoids and in particular from curcumin which are phenolic compounds with broad spectrum of biological activities. Indeed, curcumin is recognized for its many properties, in particular its antioxidant, anticancer and in the prevention and treatment of cardiovascular diseases (Ravindran et al. 2007; Ashraf and Sultan 2017). To these properties it could be retained the many other properties of flavonoids and alkaloids in particular their ability to "absorb" free radicals, anticancer, anti inflammatory, anti bacterial, antiviral, analgesic, anticonvulsive, bacteriostatic, fungicide, sedative, antiallergic, cholesterol-reducing …(Kabera et al. 2014; Abraham et al. 2018), which make turmeric a plant to promote. Alteration of secondary metabolites would occur during longer heat treatment even at lower temperatures (Vega-Gálvez et al. 2012). However, according to Ahmad et al. (2016) studies, higher level of curcumin contents were found in sun dried samples (7.3%) as compared to samples dried in mechanical dryer (5%). This may be due to high temperature of the drier which was maintained at 60 ° C for 3 days due to which degradation of curcumin occur. There is only a small difference in the curcumin content of turmeric rhizomes dried in both the methods. This small difference in the curcumin content of turmeric rhizomes dried by two different methods (sun drying versus solar drying) was also observed by Gunasekar et al. (2006) and Sharma et al. (2008), who also found higher retention of total curcumin content in sun dried samples. Curcumin loss during heat processing of turmeric varied from 27 to 53% with maximum in pressure cooking for 10 min (Jayashree and Zachariah, 2016). Although, the higher temperature in mechanical drying caused a slight loss of curcumin and

oleoresin, the product is still satisfying the specified requirements. Nevertheless, the mechanical oven drying method is the best possible option for drying of turmeric rhizomes (Ahmad et al. 2016).

Conclusion

Processing of raw turmeric rhizomes is a challenge with respect to its final quality. The processing of turmeric rhizomes consists of three stages: peeling, blanching and drying. The results of this study showed that the production treatment condition in particular peeling and blanching have an influence on the physico-chemical, microbiological and sensory quality of the infusettes. These observations were confirmed by the mass loss during peeling which induced a significantly lower yield. Blanching enhanced water removal during drying and provided a product with lower moisture content. Since moisture content of product obtained by different processes varied, the production yield was also significantly different. Microbiological analysis showed that they were a satisfactory microbiological quality of all samples due to the effectiveness of peeling, blanching and drying conditions. Organoleptic evaluation revealed that the product obtained by the peeling process had better yellow-orange color, aromatic odour, slightly hot taste and better clarity on hot water. The presence of various secondary metabolites with recognized therapeutic properties in Curcuma longa was observed on all samples produced and was not depended on the process. Hence, peeling, blanching and mechanical drying can safely be adopted to develop post harvest processing method for turmeric drying at commercial level in order to get good quality product.

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