

Postharvest treatments of wild pepper (*Piper* spp.) in Madagascar

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Postharvest treatments of wild pepper (*Piper* spp.) in Madagascar.

Abstract – Introduction. A study on postharvest treatments of wild peppers was carried out in Madagascar with the aim of describing the local practices and measuring their impacts on the quality of the products. **Materials and methods.** Four distinct pepper production systems (PPS) were observed, described and compared in two separate areas in East Madagascar. Major quality characteristics (piperine and essential oil) of the peppercorns were assessed in samples collected in the four systems. **Results and discussion.** Two main postharvest processes (dry and wet) were identified. The wet process differed from the dry one in that it involved two specific operations, blanching and sweating. The processes influenced the color of the pepper. Piperine contents were not affected by any of the pepper production systems, whereas essential oil contents were reduced by up to 27% by the wet process. After processing, piperine contents were up to eight times lower, whereas essential oil contents were up to six times higher than the specifications of the standard ISO 959-1 for black pepper ready for commercialization. **Conclusion.** Two main processes (dry and wet) for treatment of peppercorns in Madagascar were identified and described. The dry process, with two steps less, appeared to be easier to implement and more respectful to the product. Improving maturity control and processing according to the quality expected by the markets will be necessary to promote Malagasy peppers.

Madagascar / *Piper* / pepper / processing / essential oils / color

Traitements post récolte du poivre sauvage (*Piper* spp.) à Madagascar.

Résumé – Introduction. Une étude des traitements post récolte des poivres sauvages a été menée à Madagascar afin de décrire les pratiques locales et de mesurer leurs impacts sur la qualité des produits. **Matériel et méthodes.** Quatre systèmes de productions (PPS) ont été observés, décrits et comparés dans deux zones définies de l'est de Madagascar. Des caractéristiques qualitatives majeures (piperine et huile essentielle) du poivre ont été évaluées sur des échantillons collectés dans les quatre systèmes. **Résultats et discussion.** Deux principaux procédés post récolte (une voie sèche et une voie humide) ont été identifiés. La voie humide diffère de la voie sèche par deux opérations spécifiques : l'échaudage et l'étuvage. Les procédés ont montré une influence sur la couleur du poivre. Les teneurs en piperine n'ont pas été affectées par les systèmes de productions quels qu'ils soient alors que les teneurs en huile essentielle ont été réduites jusqu'à 27 % par la voie humide. En fin de procédés, les teneurs en piperine ont été jusqu'à huit fois plus basses et les teneurs en huile essentielle jusqu'à six fois plus élevées que celles spécifiées dans la norme ISO 959-1 pour le poivre noir prêt à la commercialisation. **Conclusion.** Deux procédés principaux (l'un « sec », l'autre « humide ») utilisés pour le traitement des poivres à Madagascar ont été identifiés et décrits. La voie sèche qui comprend deux opérations en moins, semble plus aisée à mettre en œuvre et mieux respecter le produit que la voie humide. Le respect de la maturité du poivre sauvage lors de la cueillette ainsi que la maîtrise des procédés en fonction des produits attendus par les marchés seront nécessaires pour mieux valoriser les poivres malgaches.

Madagascar / *Piper* / poivre / traitement / huile essentielle / couleur

1. Introduction

Since antiquity, spices and herbs have been used throughout the world to enhance flavor and preserve food, as well as for medicinal and cosmetic purposes [1]. They were highly sought after, much like gold. Today spices are no longer luxury items, but they are in high demand and their importance is still growing [2].

The genus *Piper* belongs to the family Piperaceae and comprises more than 700 species distributed throughout tropical and subtropical regions of the world [3]. Among this huge diversity, one species, *Piper nigrum*, represents the vast majority of the 435,000 t of pepper (*Piper* spp.) produced in the world in 2011 for a value of 900 M\$¹. This black pepper (*Piper nigrum*) is used extensively; it is known as the king of spices as it is the most popular spice worldwide. It has been the subject of several studies showing, for instance, that it can be transformed by dry or wet processes. Dhas and Korikanthimath described the various types of operations such as blanching (wet process), cleaning or drying [4]. The impacts of some of these operations on black pepper quality were assessed by Nisha *et al.* [5], who showed piperine stability after heat processing with only 5% loss after 20 min at 100 °C. Using the same process, essential oil was reduced by about 30%. Similarly, Suresh *et al.* observed a maximum piperine loss of 34% in black pepper cooked under pressure for 10 min [6].

However, most peppers remain non-cultivated wild species, mostly handpicked in limited quantities and consumed locally. To our knowledge, no scientific studies have been published on wild peppers. One or several wild pepper species that do not belong to *P. nigrum* (genetic determination is ongoing), locally named Tsiperifery, grow in Madagascar's primary rainforests. Part of the Tsiperifery production, estimated at (30 to 50) t of dry product per year (unpubl. results) is collected and transformed for local consumption or export. These Malagasy wild

peppers, little known compared with *P. nigrum*, have started to gain fame in French gastronomy. The literature is thus very scarce but there is a need to acquire knowledge about the transformation processes.

In our study we describe the main local postharvest treatments of wild peppers (*Piper* spp.) in the East coast forest corridors of Madagascar and assess the impacts of these processes on some main quality characteristics, *i.e.*, essential oil and piperine contents, and visual aspect.

2. Materials and methods

2.1. Wild pepper production systems

In Madagascar, although September to December is the most suitable period, it is possible to find mature wild pepper almost throughout the year, *i.e.*, from April to January. Our study (sampling included) was carried out from July to November 2012 in two different zones (zones 1 and 2), located between the Madagascar highlands (≈ 100 km from Antananarivo, the capital) and the primary rainforests of the East coast (north of Moramanga), both at an altitude between (900 and 1300) m (*figure 1*). These zones were selected because chief local traders described them as being the main locations from which most Malagasy wild pepper is collected. Our study was not easy to carry out because the actors were difficult to reach most of the time and several hours' walking was needed to reach picking and collecting sites in both areas. Nevertheless, four distinct pepper production systems were selected as study cases in the two zones (*table 1*). One pepper production system (PPS1) was located in zone 1 (Angavo forest corridor zone), and the other three pepper production systems (PPS2, PPS3 and PPS4) were in zone 2 (Ankaï forest corridor zone). The pepper production systems PPS1 and PPS2 were operated by Madépices Company (Antananarivo). The pepper production systems PPS3 and PPS4 were operated by Cent. Techn. Hortic. Tamatave (CTHT) and SOPRAL Co. (Tamatave), respectively. These actors produce annually

¹ FAOSTAT, <http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor>, 30 Oct. 2013.

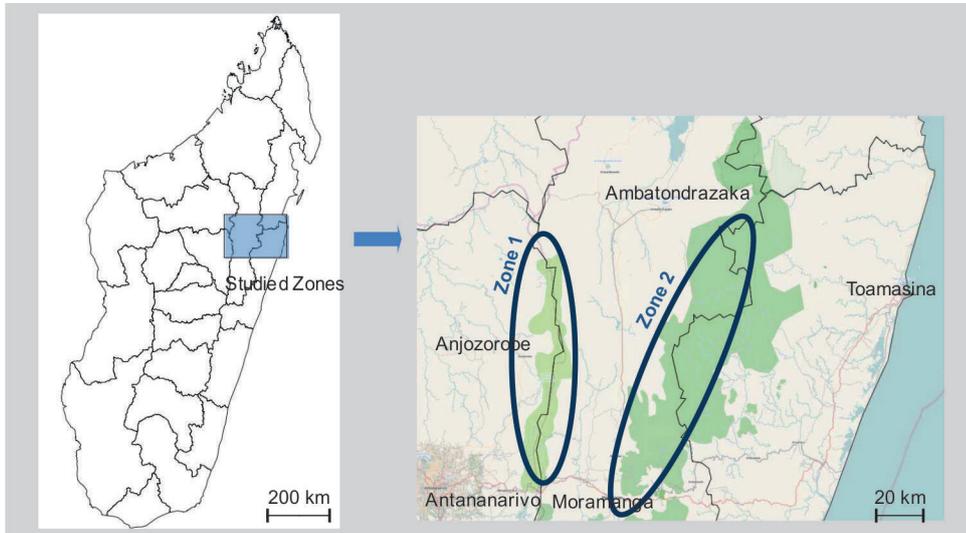


Figure 1. Zones selected for studying postharvest treatments of wild pepper (*Piper* spp.) in Madagascar: Zone 1, Angavo forest corridor; Zone 2, Ankaï forest corridor.

Table I.

Mean values of piperine ($n = 3$) and essential oil ($n = 2$) contents at different steps (t_0 and t_1) of the postharvest processes of wild pepper with samples collected in two different zones of Madagascar (zone 1: from 40 km to 100 km northeast of Antananarivo; zone 2: from 0 km to 100 km north of Moramanga) in four distinct pepper production systems (PPS1, PPS2, PPS3 and PPS4: see figure 2).

Postharvest process	Zone	Reference	Process step	Content in 100 g of dry matter Piperine (g)	Essential oil (mL)
Dry process	1	PPS1	t_0	2.3	12.4
	1	PPS1	t_1	2.8	11.7
	2	PPS2	t_0	3.4	13.1
	2	PPS2	t_1	3.1	13.4
Wet process	2	PPS3	t_0	0.5	6.9
	2	PPS3	t_1	0.5	5.6
	2	PPS4	t_0	1.2	2.8
	2	PPS4	t_1	1.2	2.0

about 15 t of dry wild pepper of a total estimated to be between (30 and 50) t; this represents between 30% and 50% of the total Malagasy production.

A checklist was used for interviewing 28 actors or groups of actors (four groups of pickers, eighteen collectors and six processors-exporters) in order to characterize the pepper production systems. The checklist included the following: (i) description of

activities (history, motivation, organization); (ii) pepper quality perception, evaluation and control; (iii) process description; (iv) commercialization (volumes collected or purchased, sales, prices); and (v) relations with other actors of the chain.

For the process description, we used the 5M methodology – a widely utilized tool in developing hazard analysis critical control point (HACCP) systems [7] – to describe

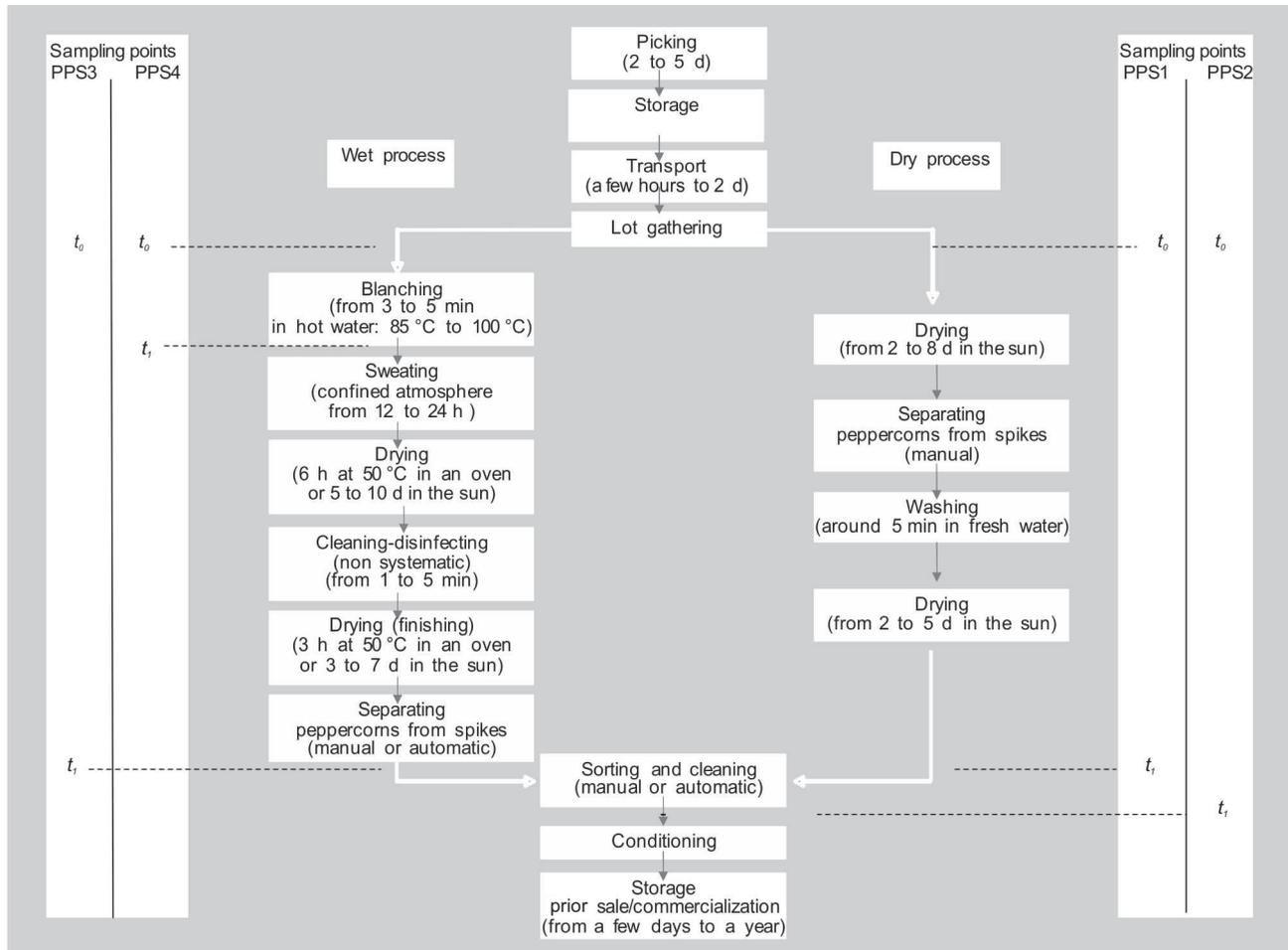


Figure 2. Diagram of dry and wet processes used for four distinct pepper production systems (PPS1, PPS2, PPS3 and PPS4) and indication of sampling (Madagascar).

each step of the four studied pepper production systems accurately and exhaustively through five dimensions: men, materials, machines, methods and the environment (“mother nature”). At least three visits per actor (pickers, collectors, processors and exporters) were made to achieve process descriptions.

2.2. Determination of peppercorn quality

Pepper samples were collected at different steps (*figure 2*) of the four pepper production systems for quality analysis.

2.2.1. Sampling procedure

Eight samples (two per pepper production system) of about 400 g each were collected at two steps (t_0 and t_1) of each of the four

systems studied in zone 1 (PPS1) and zone 2 (PPS2, PPS3 and PPS4). In PPS1, PPS2 and PPS3, the two samples corresponded to the beginning (t_0) and the end (t_1) of the processes. In PPS4, as the objective was to determine the impact of blanching, t_0 and t_1 corresponded to the steps just before and just after the critical step, respectively. All samples were carried to the laboratory and stored at -80 °C before analysis. The practices observed in the field consisted of collectors gathering lots picked by different pickers in various places (in our defined zones). The samples thus collected in each zone were a mixture of peppers (various species) from different plots (with possibly different climates and soils) at various stages of maturity. We ensured, however, that peppers had not been mixed between t_0 and t_1 in the four pepper production systems.

2.2.2. Sample preparation

Each sample was thawed for 24 h at 50 °C in an oven (Memmert ULE 400, Memmert GmbH, Germany). Peppercorns with peduncles were then manually separated from fruit stems before being ground for 10 s at 10,000 rpm with a cutting mill (Retsch - Grindomix GM 200, Retsch GmbH, Germany).

2.2.3. Analytical methods

2.2.3.1. Dry matter content

The dry matter content was obtained by drying 5 g of ground pepper in an aluminum cup in the oven at 105 °C for 30 h (*i.e.*, until constant weight). Initial and final masses were determined with a precision balance (Scaltec SBC 22 model, Scaltec GmbH, Germany). The maximum standard deviation of repeatability was $\pm 0.1\%$ with $n = 3$.

2.2.3.2. Piperine content

The piperine content, expressed on a dry basis, was determined according to the spectrophotometric global method described in the standard ISO 5564 [8]. The spectrophotometer used was a Thermo Spectronic Helios α v4.60 (Thermo Fisher Scientific, USA). The maximum relative deviation of repeatability was $\pm 12\%$ with $n = 3$.

2.2.3.3. Essential oil content

The essential oil content, expressed on a dry basis, was determined using a method adapted from the standard ISO 6571 [9]. One modification in the applied method was the elimination of xylene. The maximum relative deviation of repeatability was $\pm 11\%$ with $n = 8$.

3. Results and discussion

3.1. Description of pepper postharvest treatments

Two different types of processes, one dry and one wet process, were identified in the studied zones. The dry process appeared to be easier to implement. The main difference

between the dry and wet processes was that the wet process included two successive steps called blanching and sweating (*figure 2*). The 5M methodology provided information on: (i) the material, *i.e.*, maturity, size, color and state of the peppercorns (fresh, wet, dry); (ii) objects, tools or equipment, *e.g.*, bags, winnows, separators; (iii) conditions, *e.g.*, inside or outside, temperature and humidity, cleanliness; (iv) the method, *i.e.*, the way each step is handled, what method was used; and (v) the persons involved in processing pepper.

The observed processes are precisely detailed hereafter. Some process steps were common to both processes, whereas others were not.

3.1.1. Picking

Picking could last two to five days depending on the time pickers spent in the forest. The methods used consisted of (i) tree climbing up to 20 m to pick fruits directly, and, more often, (ii) uprooting vines or even (iii) cutting off live supports with machetes and axes. The last two methods are considered as having a negative impact on the pepper resource, and sometimes even on the forest after the trees have been logged. The maturity of the picked peppercorns was very heterogeneous (*figure 3*, fresh wild peppercorns at t_0) for the following reasons: vine fructification within the same area could last several months, spike maturity varied on the same vine, and fruit maturity also varied on a given spike. This heterogeneity of maturity affects the size and color of the peppercorns. After picking, the gatherers separated the spikes from the vine and leaves. Sometimes pickers kept the spikes (covered with fruits) in their hats and pockets before putting them into plastic bags. The quantity of pepper picked by one picker varied from (1 to 20) kg per day.

3.1.2. Storage

Storage was repeated between several steps of the production systems. After picking, transport or gathering, intermediary storage consisted of a period that could last of from one to five days depending on the practices, the time spent by the gatherers in the forest, and the distance between the forest and

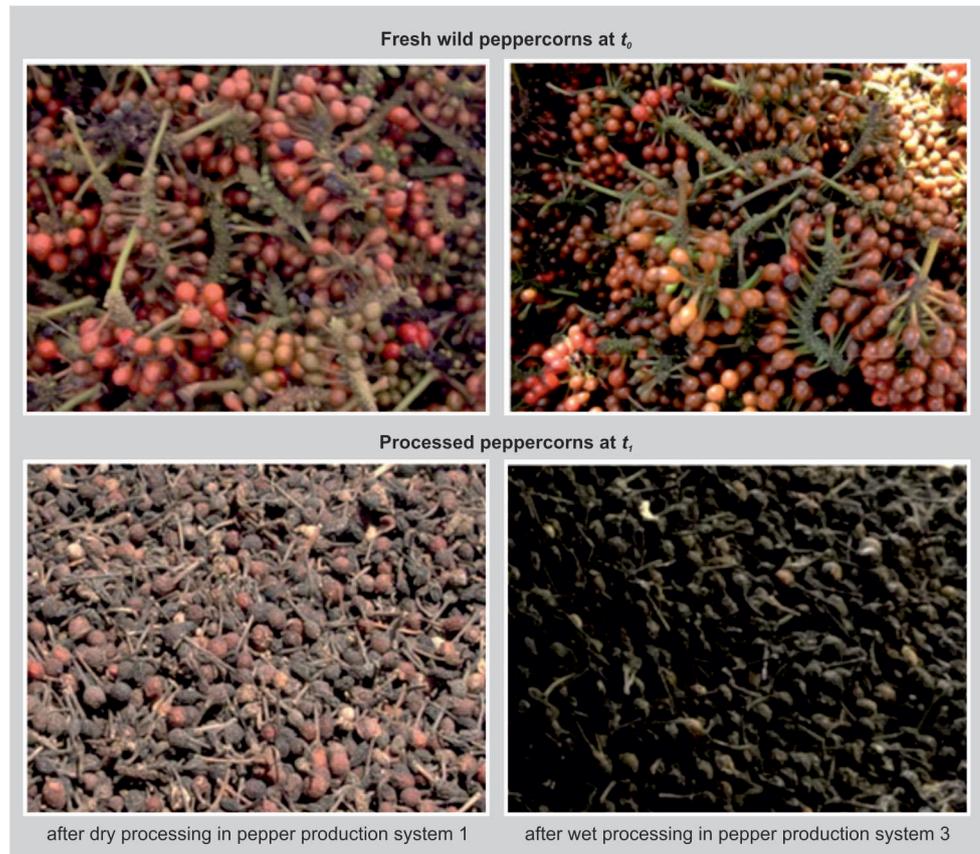


Figure 3. Fresh wild peppercorns at t_0 , and processed peppercorns at t_1 either after dry processing in pepper production system 1 or after wet processing in pepper production system 3 (Madagascar). A color figure is available at www.fruits-journal.org.

village markets or collecting points. Pepper spikes were kept in plastic bags that were sometimes hung above ground to protect them from animals. At night, the pepper was sometimes spread on the plastic bags or on banana leaves.

In their final storage phase before conditioning or before commercialization, peppercorns could be kept for more than a year in baskets made of natural local fibers, in plastic buckets or in individual conditioning polyethylene or polypropylene bags.

3.1.3. Transport

Transport could take from a couple of hours to two days depending on the distances and means used: by foot, bicycle, motorbike, bus and, less frequently, car. It was repeated each time pepper was traded from one actor to another as gatherers, collectors and distributors were generally located in different places. Peppers, which were only partially

dried, were usually kept in plastic bags during transport.

3.1.4. Gathering the lots

Gathering could be performed by primary and secondary collectors (who collected from a few to one hundred kilograms a week) as well as by distributors (up to one ton). It consisted of transferring pepper from one container to another (usually larger) without consideration of quality except at the distributors' level. The containers, usually plastic bags of different sizes, were sometimes made of natural fibers such as burlap.

3.1.5. Drying

Drying was carried out by various actors and repeated at different steps during the process: reduction in water content ensured peppercorn preservation essentially by limiting microbial growth. The dry matter content

measured in fresh peppercorns at the beginning of the drying step ranged from 26% to 30%. In PPS3, drying was conducted in thin layers on racks made of synthetic fiber in an oven at 50 °C for (6 to 12) h. In PPS1, PPS2 and PPS4 it was conducted in the sun on or above ground, and the pepper was kept inside (spread out or not) during rainy periods and at night. The support types (palm mats, drying racks in natural or synthetic fibers, or plastic sheets) and the height of the layers, that were or were not regularly turned, changed according to the actors in the various systems. Sun-drying periods, continuous or not, lasted from two to almost fifteen days depending on the pepper lots, the actors' know-how and availability, and the climate. It must be emphasized that, depending on the time of the day, the season and the zone, the temperature and humidity varied from 15 °C to 35°C and from about 40% to 90%, respectively. At the end of drying, the dry matter measured (*e.g.*, 95% in PPS1 and 93% in PPS2) was all above the 87% minimum value specified in the standard ISO 959-1 for black pepper ready for commercialization. Partial staking and sorting (*e.g.*, removal of foreign matter, leaves and spikes) were also routinely performed during drying.

3.1.6. Separating peppercorns from spikes

This step consisted of separating berries from spikes. It was easier to perform after drying but was sometimes carried out during drying. It was usually done manually by rubbing spikes against one another, by threshing, by trampling, or by rubbing spikes on an abrasive object such as a metal colander to facilitate separation, but this last method damages peppercorns. An automatic separator (a pilot made by Sunthesis, Antananarivo, Madagascar) was used in PPS3 and PPS4.

3.1.7. Sorting and cleaning

The various actors partially sorted and cleaned the peppercorns throughout the process, activities which were usually finalized by the distributor or the exporter before conditioning and storage. Sorting served to eliminate foreign matter, dirt, and immature

and lightweight aborted or broken berries. It was usually carried out manually or with a winnow and, more rarely, with a densitometric separator (such as the cyclone separator, a pilot made by Sunthesis and used in PPS3). Separate batches could then be classified into different pepper commercial categories.

3.1.8. Conditioning

The distributors conditioned peppercorns by packing them into sale units. The materials used were in direct contact with the product and were made of one or several layers of polyethylene or polypropylene. In PPS3 and PPS4 peppercorns could be packed under partial vacuum.

3.1.9. Washing (dry process only)

The washing phase, observed in PPS1 and PPS2, was carried out with fresh tap water on dry peppercorns when their dry matter content was about 93%. The peppercorns were hand-washed in a colander set inside a plastic bowl for around five minutes. Floating impurities and dust were removed with a small steel strainer. The operation was usually repeated twice before the peppercorns, whose dry matter content decreased from 93% to 61% in PPS1 and from 93% to 74% in PPS2, were set to dry again.

3.1.10. Blanching (wet process only)

Blanching (sometimes called bleaching or scalding) consisted of dipping peppercorns either directly or inside a net (mosquito-net type) or in a basket made of natural fibers or in a metal colander into simmering or boiling water (100 °C) for (3 to 5) min. The pepper was then drained. Blanching is used, according to Dhas and Korikanthimath [4], not only to remove impurities (dust and foreign matter) and decrease the microbial load but also to increase the speed of drying that follows. Blanching also allows the development of a uniform browning by promoting oxidation of phenols by phenolase enzymes [10] or by other browning mechanisms that have not yet been determined [11].

3.1.11. Sweating (wet process only)

Sweating was performed immediately after blanching and consisted of storing pepper

inside or in the shade and above ground, in a confined atmosphere, *i.e.*, burlap, fabric or plastic bag for (12 to 24) h. According to some PPS3 and PPS4 actors, the practice of combining blanching and sweating had been implemented according to the method used for traditional vanilla bean curing, which was described by Odoux *et al.* [12]. Indeed, in vanilla processing, the curing step triggers enzymatic reactions that contribute to aroma development.

3.1.12. Cleaning and disinfecting (wet process only)

Cleaning and disinfecting were not systematic. They were sometimes observed before blanching in PPS3, but were more often carried out in PPS4 after a first drying operation. In addition to washing the product, this step aimed at reducing microbiological contamination when there was presumption or proof of microorganism development (*e.g.*, presence of white mold on the surface). To do so, pepper was soaked in chlorine water in plastic bowls for (1 to 5) min. The available chlorine ranged between (6 and 50) $\mu\text{L}\cdot\text{L}^{-1}$. These concentrations are much below those proposed in the European standard EN 13697, that recommends 260 $\mu\text{L}\cdot\text{L}^{-1}$ with a contact time of 15 min for efficient disinfection [13].

3.2. Determination of some quality characteristics of the peppercorns

The visual aspect (color and size), pungency, aroma of the peppercorns and homogeneity of the batches were the quality criteria that were the most cited by the various actors. We decided to consider the visual aspect, and essential oil and piperine contents, as all three are cited in the standard ISO-959-1 [14].

There are more piperine and essential oil in the pepper used as a raw material in PPS1 and PPS2 than in PPS3 and PPS4. These differences could be due to the origins (climate and soils, for instance), maturity and species of the different lots of wild pepper.

3.2.1. Piperine content

At the beginning of the process (t_0), the piperine contents were measured in the four samples collected after gathering the lots. They ranged from 0.5% to 3.4% (dry basis) (*table D*). The rates of 0.5% to 3.1% obtained in samples after treatments (t_1) were all below (and up to eight times lower than) the 4% content recommended by the standard ISO 959-1 [14]. Our analysis also revealed that the processes, whether wet or dry, had no impact on the piperine contents of the peppercorns. This result agreed with those of Nisha *et al.* regarding the kinetic reaction rates of piperine degradation during heat treatment [5]. However, it differed from that reported by Suresh *et al.*, who obtained about 25% loss in peppercorns after heat processing [6].

3.2.2. Essential oil content

At the beginning of the process (t_0), the contents of essential oil measured in samples collected after gathering the lots (*table D*) ranged from 2.8% to 13.1% (dry basis). The 2.0% to 13.4% rates found in the samples after treatments (t_1) were all higher (and up to six times more than) the 2% rate indicated in the standard ISO 959-1 [14]. The dry process did not impact the essential oil content, whereas the wet process reduced the essential oil content of peppercorns by up to 28%. In a study on rosemary, Szumny *et al.* reported a reduction of around 40% in the essential oil content when they treated the leaves for 30 min at 60 °C [15].

3.2.3. Visual aspect

Considering the evolution of wild peppercorns at the beginning (t_0) and at the end (t_1) of PPS1 and PPS3, in both processes, the fresh peppercorns (t_0) used as raw material appeared to be heterogeneous in size and color (*figure 3*). Their lengths varied from (0.2 to 0.6) cm and their sections from (0.2 to 0.5) cm. Color ranged from green to deep purple, with red dominant. This heterogeneity reflected the many differences in maturity. After treatment (t_1), the lengths and sections of the peppercorns were all reduced to values between (0.1 and 0.4) cm. The color of peppercorns dry-processed in

PPS1 appeared lighter with a majority of gray and some light purple, whereas the peppercorns wet-processed in PPS3 appeared black and dark gray (*figure 3*). In both cases, the heterogeneity of colors was reduced by the processes, especially in the wet process.

4. Conclusion

We described the local processing practices of Malagasy wild pepper in detail through the study of four pepper production systems located in two separate areas, known as the main picking and processing zones for this product in Madagascar. Observing and describing the four pepper production systems in these areas has been quite a challenge because the systems were informal, and it was difficult to reach the locations and schedule meetings with the various actors. Despite the lack of structure for this wild pepper commodity, two main processes (dry and wet) were identified and analyzed. The dry process appeared to be more respectful to the product and easier to implement; indeed, the wet process differed from the dry one in that it included two additional operations: blanching and sweating. Piperine was not affected by the type of production system, whereas essential oil was reduced by the wet process. After processing, piperine was up to eight times lower and essential oil up to six times higher than the specifications of the standard ISO 959-1 for black pepper ready for commercialization [14]. Improving maturity control and processing according to the quality expected by the markets will be necessary to promote Malagasy peppers.

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Tratamientos postcosecha de la pimienta silvestre (*Piper* spp.) en Madagascar.

Resumen – Introducción. Se realizó un estudio de tratamientos postcosecha de las pimientas silvestres en Madagascar con el fin de describir las prácticas locales y de medir sus impactos en la calidad de los productos. **Material y métodos.** Se observaron, describieron y compararon cuatro sistemas de producciones (PPS) en dos zonas definidas del este de Madagascar. Se evaluaron características cualitativas mayores (piperina y aceite esencial) de la pimienta en muestras recolectadas en los cuatro sistemas. **Resultados y discusión.** Se identificaron dos procesos principales postcosecha (una vía seca y una vía húmeda). La vía húmeda difiere de la vía seca por dos operaciones específicas: el escaldado y el secado. Los procesos mostraron una influencia en el color de la pimienta. Los contenidos de piperina no fueron afectados por ningún sistema de producción, independientemente de cuál fuera, mientras que los contenidos de aceite esencial se redujeron hasta un 27 % por la vía húmeda. Al final de los procesos, los contenidos de piperina bajaron hasta ocho veces y los contenidos de aceite esencial aumentaron hasta seis veces, en comparación con aquéllos que se especifican en la norma ISO 959-1 para la pimienta negra lista para la comercialización. **Conclusión.** Se identificaron y describieron dos procesos principales (uno « seco », otro « húmedo »), empleados para el tratamiento de las pimientas en Madagascar. La vía seca, que comprende dos operaciones menos, parece más fácil de ejecutar y respetar mejor el producto que la vía húmeda. Para valorar mejor las pimientas malgaches será necesario respetar la madurez de la pimienta silvestre en el momento de la cosecha, así como controlar los procesos en función de los productos esperados por los mercados.

Madagascar / *Piper* / pimienta / procesamiento / aceites esenciales / color