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Original article

Effect of drying process on lemon verbena (*Lippia citrodora* Kunth) aroma and infusion sensory quality

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Summary Lemon verbena leaves are used as herbal infusion due to their aromatic, digestive and antispasmodic properties. The aim of the present study was to determine the sensory quality of lemon verbena infusions prepared with fresh leaves, dried leaves at 30 °C and 60 °C. Infusion aroma and taste was determined through a trained sensory panel and an electronic nose (e-nose). Infusion acceptability was evaluated through a consumer test. All drying treatments on day 0 were grouped together regarding the e-nose determination. 'Floral' descriptors were related to leaves not submitted to store. When the leaves were stored for 30 days, aroma attributes were lost. Differences on the infusion acceptability were ascribable to the drying method. Infusions prepared with fresh leaves showed the highest acceptability. E-nose could be used as a reliable tool for characterising the quality of aromatic herbs.

Keywords Electronic nose, food quality, herbal infusion, organoleptic properties, peaches, post-harvest.

Introduction

Lemon verbena (*Lippia citrodora* Kunth) is a *Verbenaceae* that grows spontaneously in South America and is currently cultivated in North Africa and Southern Europe (Carnat *et al*., 1999). The leaves are used for herbal infusion because of their aromatic, digestive and antispasmodic properties. Lemon verbena leaves have a gentle sedative action and a reputation for alleviating abdominal discomfort. Fourteen compounds have been identified, among these geranial and neral were detected as the most frequent, while α-pinene, β-pinene, and β-caryophyllene were the minor components (Kim & Lee, 2004). The principal volatiles of lemon verbena, assessed by GC/MS, are phytol (11.6%), spathulenol (7.1%), and caryophyllene oxide (5.6%) (Crabas *et al*., 2003). The content of the essential oil of lemon verbena leaves range on 0.2–1% on dry weight, mainly composed (10–40%) by citral (neral and geranial), and limonene, cineole, geraniol, β-caryophyllene and spathulenol and its composition and content vary depending on genotype and harvest time (Carnat *et al*., 1999).

The production of high quality aromatic herbs requires an excellent raw material, which implies good farm procedures, correct harvest date, adequate industrial processing and storage conditions; all steps that would affect the final sensory quality of the product. The aromatic herbs should be dehydrated for keeping quality for long periods and there are different methods for dehydrating herbs and the election of which to use will depend on the product characteristics and economics considerations. Leaf dehydration, besides water elimination from tissues, produces changes on chemical, biological, and physical properties, as well as on the texture, colour and aroma (Hevia & Tramón, 2003). The aroma of herbs and infusions is measured by means of sensory panels, but other techniques that could easily determine aroma in herbal products are being investigated. Among these, there is the electronic nose (e-nose) technology, used on different studies for food evaluation and classifying products according to their aroma (Hernandez Gómez *et al*., 2007; Benedetti *et al*., 2008; Esposto *et al*., 2009). On *Ilex paraguariensis* ('yerba mate') infusions the e-nose data showed high correlation with aroma, mouth feel and sweetness attributes, indicating that this methodology is a good complement to sensory evaluation (Grigioni *et al*., 2004).

The aim of the present study was to determine the sensory quality, particularly the aroma component through an e-nose of lemon verbena infusion prepared with fresh and dried leaves, immediately after leaf processing and after 30 days of storage.

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Materials and methods

Plant material

Lemon verbena leaves used in this study were obtained from a selected clone (PUCV-02) from the germoplasm repository of the Catholic University of Valparaiso, Chile.

Leaf drying

At the beginning of the summer period, lemon verbena shoots of 30–70 cm long were collected during the early morning and transferred in a portable cooler to the laboratory. Detached leaves were submitted to drying treatments with hot air- and freeze-drying. For hot air drying, leaves were submitted to two temperatures (30 °C and 60 °C). Leaves were transferred to a semi-industrial drying tunnel of 1 m^3 volume chamber, equipped with butane gas burners as heat source. The leaves were maintained in the tunnel until weight stabilisation confirmed as no weight changes between two successive controls carried out each 20 min to a sample of leaves. For freeze drying treatment, the fresh leaves were frozen to −80 °C and subsequently distributed in paper bags and freeze-dried for 24 h in a Plus 12 L volume lyophiliser (Labconco Corporation, Kansas City, KS, USA). After drying, leaves were stored in paper bags at 22 °C and 40% relative humidity till evaluation.

On the same day of evaluation (0 and 30 days), fresh leaves were harvested again and stored in plastic bags at 4 °C and used as a control treatment (fresh leaves).

Electronic nose (e-nose) analysis

The e-nose EOS 835 (SACMI; Imola, Italy) was used to assess the first two principal components that determine the aroma of lemon verbena leaves. Each sample (composed sample of 2.5 g) was placed in a glass-tight container (1500 mL) for 10 min at 22 °C. Gas sampling was obtained from the head space. The instrument, equipped with six metal oxide semiconductor sensor-array, was configured with the following program: pre-acquisition phase 30 s; acquisition phase 180 s; post- acquisition phase 30 s, waiting phase 180 s and chamber cleaning phase 100 s. The gas carrier used was an instrumental synthetic air. In all determinations the same flow (150 mL s^{-1}), chamber temperature (22 °C), and relative humidity (80%) were used. The e-nose registered, during the acquisition phase, a set of data (values of electric resistance in Ohm) for each one of the six sensors. These data were subjected to the 'single point' algorithm (SACMI, Imola, Italy) based on the average of the highest electric resistance score registered. Then, each measurement was identified through a six component vector array and it was presented in a two dimension plot.

Sensorial analysis

The descriptors of the product were established through focus group discussions on eight sessions of 45 min each, with the participation of 12–15 trained panel assessors. Eight descriptors ('mint', 'lemon', 'eucalyptus', 'wild flowers', 'anis', 'fresh herb', 'dry herb', and 'wet soil') that define aromatically infusions, and five descriptors ('sourness', 'sweetness', 'acidity', 'persistency', and 'astringency') that define infusion taste were defined. Afterwards, these descriptors were used on this study. The quantitative descriptive analysis method was applied. The evaluation guidelines considered a continuous scale for each descriptor, ranging from 0–15, marked with two anchors, 0 = lowest level for that specific attribute and 15 = highest level for that specific attribute, which was used before for fresh fruit quality assessment (Infante *et al*., 2008).

Acceptability was determined through a hedonic scale, marked with two anchors, 0 = dislike (extreme), and 15 = like (extreme). Percentage of acceptance was calculated as the number of assessors liking the sample (score > 7.5) divided by the total number of assessors tasting the sample.

Preparation of the samples

Infusions were prepared by mixing 1 L of filtered tap water at 75–85 °C with 5 g of dried leaves for the 30 °C and 60 °C dried and freeze-dried treatments, and with 20 g of fresh leaves for the control. The leaves were maintained for 5 min in the water and then the infusion was drained. Afterwards, the infusions were maintained in a thermos till the panel evaluations. Four white porcelain containers with 50 mL of infusion at 40–50 °C corresponding to each treatment were presented to each assessor. Containers were marked by a 3-digit code randomly assigned, which corresponds to the same code presented on a separated evaluation guideline.

Data analysis

A completely randomised experimental design was utilised with four treatments (fresh leaves; tunnel-dried leaves at 30 °C; tunnel-dried leaves at 60 °C; and freeze-dried leaves). Ten replications for the e-nose evaluation were utilised. The Nose Patterns (SACMI; Imola, Italy) program was used, and data were presented in a two-dimensional plot design. In order to determine the association among quality attributes, a Principal Component Analysis (PCA) was performed on the same factorial design. Clusters were segregated through a non-hierarchical cluster analysis (Infostat, 2008). For the sensory evaluations twelve replications were used, which correspond to each trained assessor.

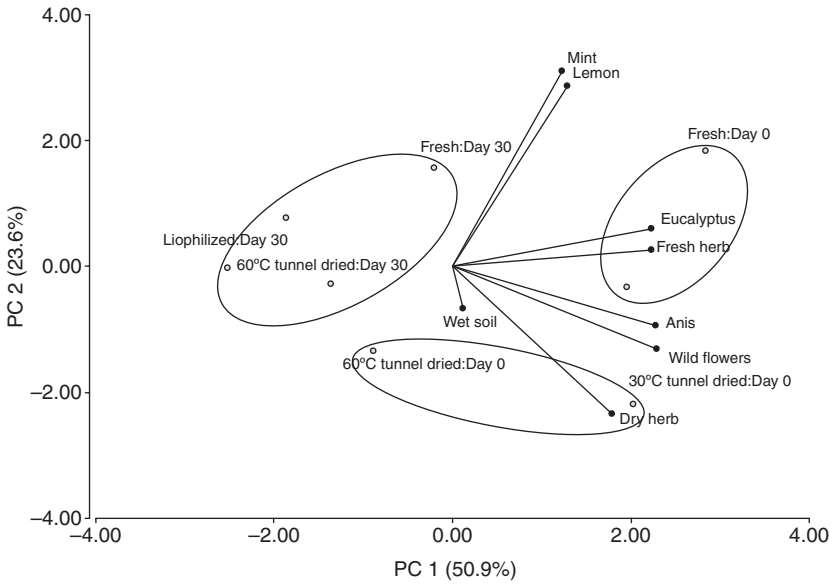

Figure 1 Principal component analysis (PCA) of aromatic descriptors of lemon verbena infusion hot air-dried in tunnel at 30 °C; 60 °C; lyophilised, and a control of fresh leaves evaluated after 0, and 30 days on storage.

The infusion acceptability was evaluated hedonically through a consumer test formed by thirty six consumers. A factorial design (4 × 2) was utilised corresponding to the four dehydration treatments described before and two storage periods (0 and 30 days post-dehydration). An ANOVA was carried out and significant differences between means were determined by the multiple rank of Tukey test (≤0.05) (Infostat, 2008).

Results

Infusion aromatic evaluation

PC1 and PC2 represented 74.5% of the total variance of the model (Fig. 1). The PC1 (50.9%) was formed by the descriptors 'dry herb', 'fresh herb', 'eucalyptus', 'wild flowers', and 'anis'. On the other hand, the PC2 (23.6%) was formed by 'mint', 'lemon', and 'wet soil' (Fig. 2). According to the cluster analysis, three groups were formed. The first corresponds to the fresh leaves and the freeze-dried treatments, all of them evaluated on day 0. This cluster appeared close to descriptors 'fresh herb', 'eucalyptus', and 'wild flowers', which are associated to herbal and flowery aromas. The second cluster grouped the two air-dried treatments evaluated on day 0. It is interesting to confirm that both treatments were near to the descriptor 'dry herb'. High temperature used for the dehydration process could affect the typical lemon verbena aroma, found on fresh leaves. The third cluster was formed by all the treatments evaluated after 30 days

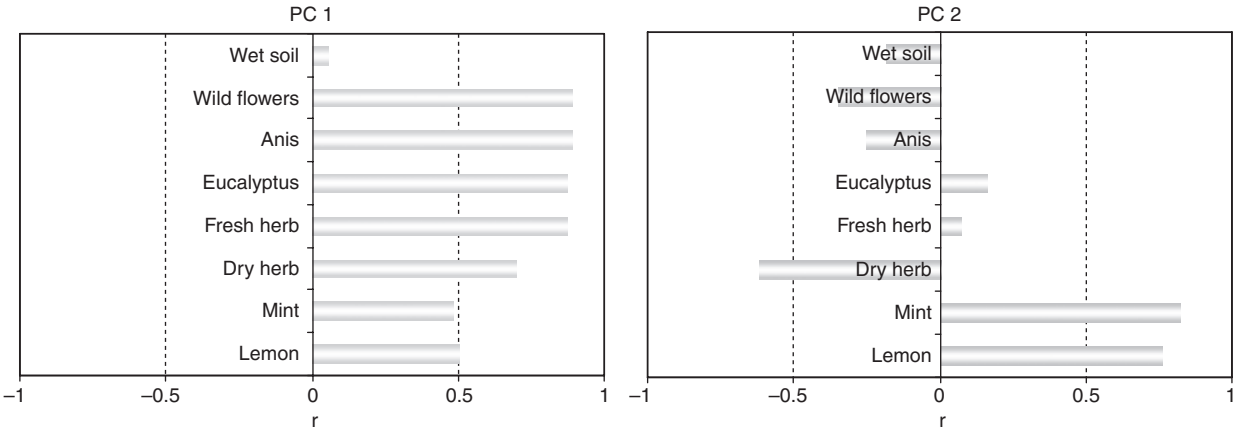

Figure 2 Correlation coefficients of the aromatic descriptors of lemon verbena infusion associated to principal component 1 (PC1) and 2 (PC2) from a principal component analysis.

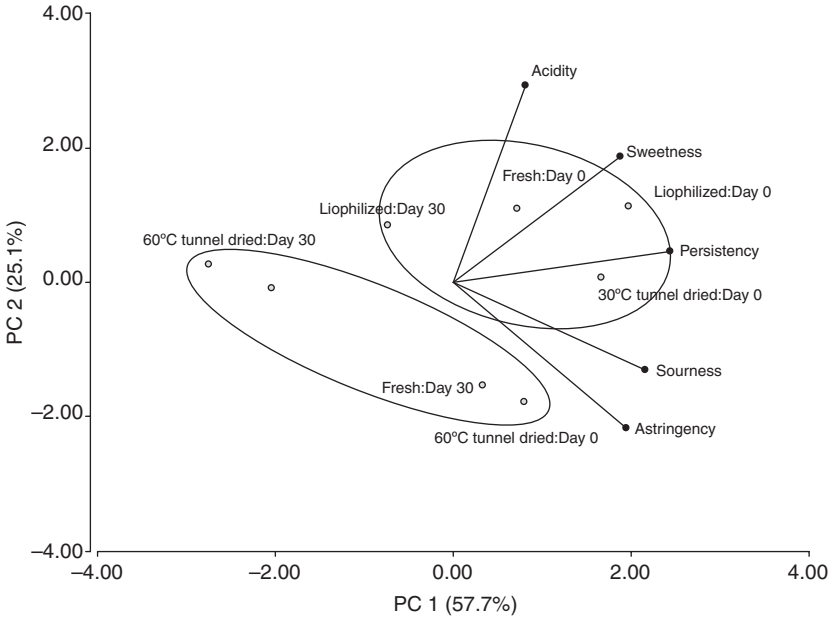

Figure 3 Principal component analysis (PCA) of sensory evaluation of lemon verbena infusion hot air dried in tunnel at 30 °C; 6-0 °C; lyophilised, and a control of fresh leaves evaluated after 0, and 30 days on storage.

of storage. This cluster was placed far from all descriptors related to the PC1, indicating that conservation affect negatively lemon verbena aroma.

Infusion sensory quality

Treatments were segregated on two clusters according to descriptors (Fig. 3). 'Sweetness', 'astringency, 'sourness', and 'persistency' were associated to PC1 (57.7%), while PC2 (25.1%) was only associated to 'acidity' (Fig. 4). Clusters were separated according to PC2 (Fig. 3), being the first cluster formed by the control, tunnel-dried at 30 °C and both freeze-dried treatments (days 0 and 30), all placed close to the descriptor 'acidity'. The second cluster grouped all other treatments far from 'acidity'.

Infusion acceptability

Differences on infusion acceptability were ascribable to the drying treatment. Fresh leaves showed the highest acceptability. The freeze-dried leaves reached

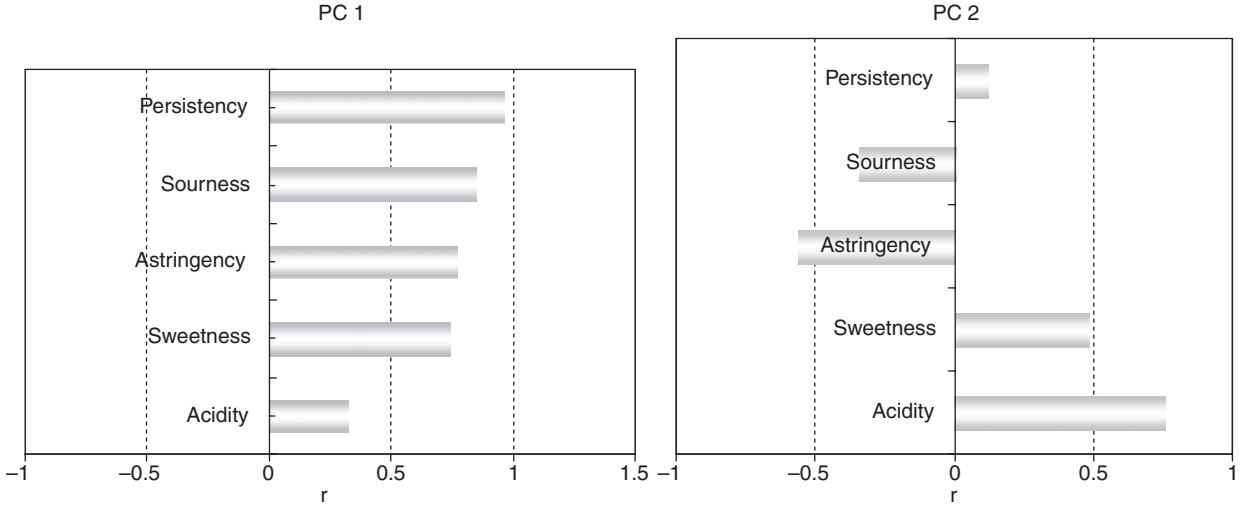

Figure 4 Correlation coefficients of the quality attributes of lemon verbena infusion associated to principal component 1 (PC1) and 2 (PC2) from a principal component analysis.

Table 1 Acceptability and acceptance of lemon verbena infusion assessed by a mini-consumer test ($n = 36$)

Drying treatment	Acceptability*	Acceptance† (%)
Fresh leaves	8.8b‡	72
Freeze-dried	7.5ab	52
30 °C tunnel-dried	7.1a	39
60 °C tunnel-dried	7.0a	37

*0 = dislike (extreme) and 15 = like (extreme).
†Number of assessors who evaluate the sample > 7.5 divided by the total number of assessors.
‡Different letters on the same column indicate statistical differences $P \leq 0.05$.

an intermediate acceptability score among the tunnel-dried treatments and the fresh leaves. The tunnel-dried treatments at 30 and 60 °C were the less accepted and they did not show differences among them. It is important to indicate that, in general, the observed acceptability scores were concentrated on the lower part of the evaluation scale (Table 1). This sensorial panel bias could be explicable by an excessive expectation of the panel or by the use of a poor quality lemon verbena genotype. It has been reported that there are qualitative and quantitative differences of the essential oils among genotypes, which differences are ascribable to the genetic background (Gil *et al*., 2007). It was observed that the infusion prepared with fresh leaves reached a higher number of satisfied consumers.

Analysis with the e-nose

When lemon verbena leaf aroma was exposed to the e-nose (Fig. 5), PC1 and PC2 hold 99.6% of the model. Differences among treatments were mainly ascribable to the storage period rather than to the drying method used, in fact two clusters that segregate treatments by storage periods (evaluated immediately after drying or after 30 days of storage) were formed. The e-nose has been used successfully for sorting and quick segregating different kinds of foods, with no need to classify them according to their biochemical composition (Plutowska & Wardencki, 2007).

Discussion

Dried leaves treatments evaluated after 30 days of storage appeared far from the sensory descriptors associated with quality. The storage temperature and humidity conditions used on this study reflect the conditions used by the industry for conserving herbs, even if they seem to be not the most appropriate for avoiding quality deterioration of the product. Storing lemon verbena leaves in controlled atmospheres, surely could improve the final quality of the product.

On the other hand, dehydrating herbs with high temperature also affect the final quality of the product. The 60 °C tunnel-dried treatment negatively affected the acceptability of the infusion, being observed a drop on the number of satisfied consumers testing the sample. High temperatures hasten the time needed for reaching a

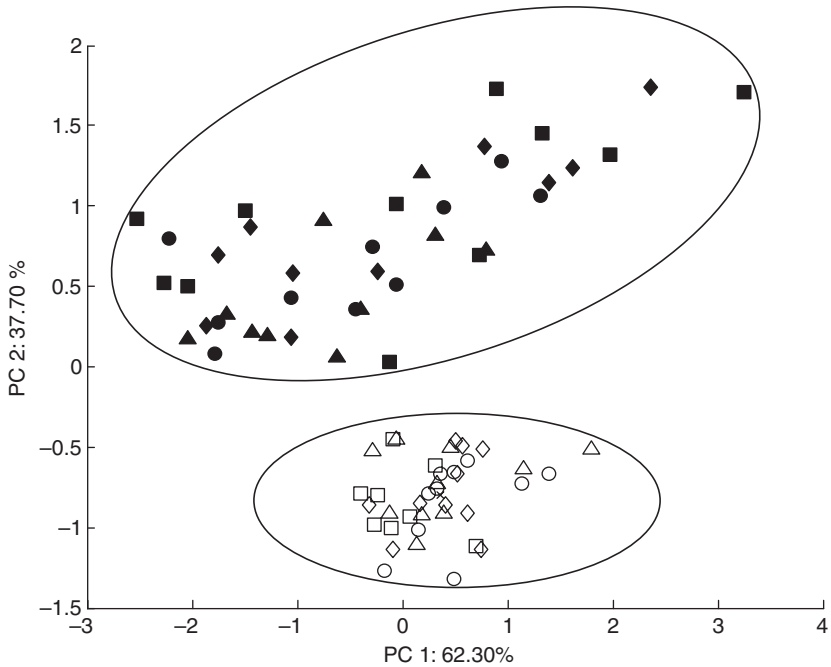

Figure 5 Lemon verbena leaves aroma evaluated through an electronic nose system EOS 835. Diamond: hot air-dried in tunnel at 30 °C; Square: hot air-dried in tunnel at 60 °C; Circle: freeze-dried, and Triangle: fresh leaves, evaluated after 0 (empty symbols), and 30 days on storage (bold symbols).

dry and stable herb; however it would negatively affect the final quality of the product (Ortiz *et al*., 2002).

Infusions prepared with lyophilised or fresh leaves showed similar acceptability, in consequence freeze-drying could be considered as a valid industrial alternative when a high quality product is sought. Furthermore, Bilia *et al*. (2008) stated that lyophilised lemon verbena leaves kept a higher content of antioxidants, mainly verbascoside, when compared with leaves submitted to other drying methods.

On this study, treatments were segregated following a similar pattern by the e-nose and by the trained panel either for leaves or infusions, being in both cases according to the storage period. These promising results encourage the incorporation of the e-nose for the industrial evaluation of sensory quality of herbs and infusions.

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