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Tropentag 2010
ETH Zurich, September 14 - 16, 2010
Conference on International Research on Food Security, Natural Resource Management and Rural Development

Application of HACCP Principles to Local Drying Processes of Capsicum Species in Bolivia and Peru

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Introduction

There are five domesticated species of the genus *Capsicum* worldwide, but the most common are *C annuum, C. frutescens, C. chinense.* Studies show that this genus has two original centers, one in the tropical and subtropical regions of Mesoamerica (Mexico, Honduras and Nicaragua) and the other in the Andean regions of Peru and Bolivia (De, 2003; Hurtado-Gonzáles *et al.*, 2008). According to Hunziker, there are 12 varieties of *Capsicum* spp. identified in Peru and 8 within Bolivia, Paraguay and Argentina (Moscone, 2007). In these areas, simple drying procedures, mainly open sun drying in the field, are still used due to low cost and easy management (Fig. 1). The process is dependent on environmental conditions and the products vary widely with respect to final quality, since extended drying times are required to reach the secure limit of moisture content and microbial contamination and development of mycotoxins are common. Unfortunately, problems faced in postharvest handling of dried capsicum have not been studied in these countries. The production needs a standard and systematic control throughout the whole process in order to avoid losses, guarantee optimal quality and increase the value on local and international markets. The aims of the this research were to identify and document species, production and uses, describe processing procedures and evaluate drying conditions and practices by applying Hazard Analysis and Critical Control Point (HACCP) principles to identify the critical control points involved in drying processes.

Fig. 1: Examples of dried capsicum production processing in Bolivia and Peru.

Material and Methods

The research was conducted between beginning of April and middle of June in Campo Redondo, Bolivia (19° 15′ 45″S, 64° 18′ 36″W) and middle of June until the end of July in Shaura, Peru (10° 25′ 00″S, 77° 43′ 00″W). The capsicum varieties focused on were those used for traditional drying practices in the study areas were: '*Huacareteño rojo*' and '*Asta de buey Amarillo*' in Bolivia (Villagómez & Blanco, 2006), belonging to the species *C. baccatum pendulum* (NB-318021, 2008) and *C. frutescens*, called 'Panca', in Peru (NTP-209.239, 1985). As the aim of the study was the identification of critical control points (CCP) in the production and processing of *Capsicum* spp., three stages were followed. The first one was regarding with the identification of the *Capsicum* spp. involved in drying processes using descriptors from IPGRI (1995) together with information from farmers who work with the crop. The second part consisted of setting climatic sensors in the drying plots of 6 farmers selected in each county that have similar processing steps. At the same time, fruit materials were collected for analyzing physical and quality characteristics in cooperation with the Institute of Food Technology (ITA) and the foundation for Promotion and Research of Andean Products (PROINPA) in Bolivia and the National Agricultural Research Institute (INIA) in Peru. The third part was to establish a multidisciplinary team consisting of 5 experts in each country and show them all the information collected in order to familiarize them with problems that farmers face during the production and processing of *Capsicum* spp. Each member gave a score on the potential hazards (biological, chemical and physical) that might present a risk point according to probability of occurrence and severity of consequence (Two Dimensional Health Risk Assessment Model). Using a decision tree based on four yes/no questions, it was then possible to confirm the identity of each risk points as a CCP as proposed by (FAO, 1998).

For the morphological characterization, 12 qualitative and 6 quantitative descriptors were chosen. The evaluation of each type of descriptor was done separately and performed in (SAS, 2008). The qualitative descriptors were analyzed by using the command of PROC CORRESP that displays correspondence analysis including the inertia decomposition and coordinates. Regarding the programming statement for quantitative descriptors, PROC PRINCOM command was used that performs principal component analysis and outputs principal components of the scores for each quantitative descriptor. For the identification of the CCPs, the responses from the HACCP teams about the potential biological, chemical or physical hazard in the production chain of dried capsicum were translated into quantitative data and analyzed using non-parametric statistics, since the values were nominal scale. The statistical analysis applied to this data was the Friedman test, where differences in the sum of the ranks were evaluated (O'Mahony, 1986; Conover, 1999).

Results and Discussion

In this study, morphological characterization was conducted for three capsicum varieties: sweet red and yellow varieties from Bolivia and one red variety from Peru. These fruit species showed high variability regarding the descriptors that are important for morphological characterization, including: fruit color at intermediate stage, fruit color at mature stage, fruit shape at pedicel attachment and fruit cross-sectional corrugation as the qualitative descriptors and fruit length, fruit minimum width and fruit weight as the quantitative. Regarding the production in Bolivia, with an average cultivated area of 0.25 of hectare, drying procedures remain mostly traditional, not only due to the topography of the region but also because of the application of organic fertilizers (although they apply pesticides at initial stage of the fruit development). In Peru, farmers have larger average cultivation areas of 3.5 hectares and the production is more mechanized with considerable applications of irrigation, fertilizers and chemical pesticides.

However, in both countries drying capsicum is done in the open sun. The main difference is related to the stage of harvest. In Bolivia, farmers mainly wait until the fruit starts to dehydrate on the plant before harvesting (indicated by wrinkled skin of the fruit). In Peru, the farmers pick fruits at a ripened stage or even harvest green fruits and sort them out in the drying area and cover them in order not to expose them to direct sunlight and complete the maturation process. According to the monitoring experiments conducted in this study, around 17 days were required to dry the fruits in Bolivia, while 25 to 30 days were required in Peru. The time need to dry the capsicum varieties was not only dependent on the different harvest stages, but also due to differences in temperature and relative humidity that were registered at the drying sites in each country (Fig. 2). Final moisture content of the samples was not found to be consistent between famers as well as the two countries.

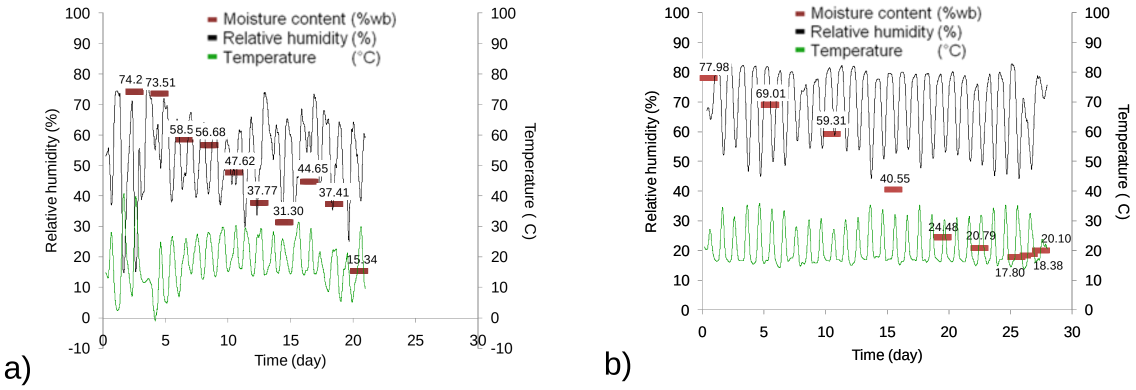

Fig. 2: Temperature and relative humidity during the drying period in Bolivia (a) and Peru (b) as related to changes in moisture content (%wb).

All the acquired information was presented to interdisciplinary HACCP teams in group settings in each country. For the identification of the CCPs, the understanding of these groups about the whole process and combination of their knowledge fulfilled FAO requirements for assessing the significance of the potential biological chemical and physical hazard analysis. Data was analyzed by summing the scores from each member of the team and then ranking in order to identify the processing step representing a potential risk point (Table 1). The identified risk points were "open sun drying" and "storage" in Bolivia, while they were "spreading on the ground" and "open sun drying" in Peru with P-values of <0.0001 and 0.042, respectively. Every risk point was also confirmed as a CCP in the production of dried capsicum for each country. The drying process was a common CCP in both countries, since this practice depends on weather conditions making it impossible to ensure control of biological, chemical and physical hazards.

Table 1: Risk identification

Processing steps	*Bolivia*	*Peru*
Seed selection	bc	bc
Fertilizer application	bcde	bc
Pesticide application	bc	bc
Irrigation	bc	c
Nursery cultivation	bc	c
Cropping site selection	bcde	bc
Planting	f	bc
Cultivation	def	bc
Harvest	cdef	b
Sorting of damage fruits	b	-
Transportation	b	bc
Piling on the ground	-	bc
Sorting	-	bc
Spreading on the ground	b	a
Open sun drying	a	a
Turning	bc	bc
Picking of the dried capsicum	cdef	-
Sorting	ef	bc
Piling on the ground	-	bc
Field packing	bc	b
Storage	a	-
Transport	bcd	bc

*same letter indicates no significant difference

As a result of this study, certain practices in Bolivia and Peru were identified as main CCPs, based on potential microbiological, chemical and physical hazards. Besides from drying practices, storage was also identified as CCP in Bolivia, where small-scale farmers store the dried capsicum in their houses made of soil bricks and tile roofs. This point was found to be a considerable issue leading to higher contamination caused by the poor economical status of the farmers. In the case of Peru, a different CCP was found to occur at the step of 'spreading on the ground'. This is mainly because the fruits contain high moisture content at this point and they can be damaged by impact on the ground, leading to a higher risk from extended drying periods.

Conclusions and Outlook

It is necessary to realize a complete morphological description of *Capsicum* spp. and combine results with a physiological study in order to identify the potential uses of this crop. The morphological assessment of fruits gives the possibility to identify the main descriptors for the studied *Capsicum* spp. Meanwhile, it was possible identify CCPs for capsicum drying following HACCP guidelines established by the FAO. From the present work, application of the HACCP system to ensure food safety in local dried capsicum production was initiated in both countries. However, corrective actions related to agricultural practices have to be made, for example by the implementation of good agricultural practices (GAP). It is very important to continue the implementation of the HACCP system in the local production and processing of dried capsicum. Based on this work, the following steps can be recommended: (i) establishment of critical limits in the production, for example, regulations on range of moisture content which will ensure minimal mycotoxin contamination, (ii) define how to monitor each identified CCP to meet the specified critical limit, for example, periodical assessment of farmer practices during the growth and production of *Capsicum* spp., (iii) realization of corrective actions such as training in the proper management of agricultural practices to ensure the identified CCPs remain in focus when considering what the problems are, how to avoid them and who the responsible actors for taking the necessary decisions are (iv) verification procedures in order to confirm the ability of controlling the agricultural and drying practices internally, including laboratory analysis of samples from the optimized procedures and (v) establishment of documentation practices regarding operations, protocols and specifications for safe production, yield reports, pesticides and fertilizer application logs and proper training of the farmers.

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