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The importance of agro-economic characteristics for minimal cassava processing: A review

A importância das características agro econômicas para o processamento mínimo da mandioca: Uma revisão

La importancia de las características agroeconómicas para el procesamiento mínimo de yuca: Una revisión

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Abstract
Cassava (Manihot esculenta Crantz) is a crop of extreme economic and agronomic value because it has several varieties, it is highly nutritious and extremely important in the food industry in the generation of products for human consumption. The objective of the present study was to characterize the culture of cassava by means of its peculiarities, potential of the product called minimally processed cassava, to describe the methods used in the generation of this product to understand the dynamics of consumption of this product. Because it is a relatively easy crop and has low nutritional requirements, cassava is grown in most of the national territory, with a growing increase in production every year. The products generated from cassava are appreciated and sold in the national and international territory, the minimally processed cassava is among the products generated by this culture, of great economic value and of great acceptance in the consumer market. The work was carried out by means of a bibliographic survey that address relevant issues about cassava and generated products, mainly minimally processed table cassava to provide an assembled and relevant knowledge to the scientific community in agri-food technologies.
Keywords: Cultivation; Food industry; Minimally processed cassava.

Resumo
A mandioca (Manihot esculenta Crantz) é uma cultura de extremo valor econômico e agronômico por apresentar diversas variedades, é altamente nutritiva e de extrema importância na indústria alimentícia na geração de produtos para o consumo humano. O objetivo do presente estudo foi caracterizar a cultura da mandioca por meio de suas peculiaridades, potencial do produto denominado de mandioca minimamente processada, descrever os métodos utilizados na geração desse produto afim de entender a dinâmica do consumo desse produto. Por ser uma cultura de cultivo relativamente fácil e de baixa exigência nutricional, a mandioca é cultivada na maior parte do território nacional, com um crescente aumento na produção todos os anos. Os produtos gerados da mandioca são apreciados e comercializados no território nacional e internacional, a mandioca minimamente processada está entre os produtos gerados por essa cultura, de grande valor econômico e de grande aceitabilidade no mercado consumidor. O trabalho foi conduzido por meio de levantamento bibliográfico que abordam assuntos relevantes sobre a mandioca e produtos gerados, principalmente a mandioca de mesa minimamente processada a fim de disponibilizar um conhecimento reunido e de relevância para a comunidade científica na área de tecnologias agroalimentares.
Palavras-chave: Cultivo; Indústria alimentícia; Mandioca minimamente processada.

Resumen
La yuca (Manihot esculenta Crantz) es un cultivo de extremado valor económico y agronómico porque tiene varias variedades, es altamente nutritivo y sumamente importante en la industria alimentaria en la generación de productos para consumo humano. El objetivo del presente estudio fue caracterizar el cultivo de la yuca a través de sus peculiaridades, potencialidad del producto denominado yuca mínimamente procesada, describir los métodos utilizados en la generación de este producto con el fin de comprender la dinámica de consumo de este producto. Debido a que es un cultivo relativamente fácil y tiene bajos requerimientos nutricionales, la yuca se cultiva en la mayor parte del territorio nacional, con un aumento creciente de la producción cada año. Los productos generados a partir de la yuca son apreciados y comercializados en el territorio nacional e internacional, la yuca mínimamente procesada se encuentra entre los productos generados por este cultivo, de gran valor económico y de gran aceptación en el mercado consumidor. El trabajo se realizó mediante un relevamiento bibliográfico que aborda temas relevantes sobre la yuca y productos generados, principalmente yuca de mesa mínimamente procesada, con el fin de brindar un conocimiento mancomunado de relevancia para la comunidad científica en el área de tecnologías agroalimentarias.
Palabras clave: Cultivo; Industria alimenticia; Yuca mínimamente procesada.

1. Introduction

Manihot esculenta Crantz is ranked as the sixth most important food in the globe, being consumed by more than 800 million families worldwide (Saravanan et al., 2016), this is certainly generated by the possibility of being produced in rustic environments, poorly fertile soils, drought tolerance, flexibility in the harvest period, as well as great energy source in human and animal food (Oliveira et al., 2013). The estimate of Brazilian cassava root production for the year 2021, according to the latest update by the Brazilian Institute of Geography and Statistics-IBGE (June 2021), is 18.7 million tons, harvested from a total area of 1.23 million hectares (Conab, 2021).

Aguiar et al. (2013) report that the commercialization of table cassava for culinary use takes place worldwide in a variety of forms, including refrigerated, frozen, precooked, and cooked, in the form of chips, "in natura", minimally processed and baked.

However, it is observed that the root has high postharvest perishability. This fact has become a challenge for producers and industries seeking to conserve and provide an increase in the shelf life of this product (Viana et al., 2010). According to Djabou et al. (2017), cassava roots when compared to other basic food crops have greater postharvest physiological deterioration in a short period of time. After the damage occurred in the roots during harvest, the physiological process of the exposed cells is balanced, causing oxidative stress of the food and consequently tissue deterioration.

It is a viable alternative to reduce post-harvest losses, minimal root processing and packaging in vacuum packaging still on rural property or in supermarkets, since there is currently a growth in this market, since consumers seek products that, in addition, have practicality (Menezes, 2012). Rinaldi et al., (2017) describe that minimal root processing involves stages of selection, classification, peeling, cutting, sanitization, rinsing, packaging, and storage. The shelf life of these minimally processed products should be sufficient to ensure the quality of food, in addition to providing food safety to the consumer (Rinaldi et al., 2017).

According to Henrique et al. (2010) these steps can lead to enzymatic darkening of the roots, since the lesions caused by processing trigger the increase in respiratory rate by exposure to oxygen from the tissue of the storage parenchyma. However, according to the cited author, the treatment of roots with antioxidants such as organic acids or bleaching, can delay the onset of darkening.

According to Vasconcelos e Filho (2010), bleaching is the heat treatment of the vegetable at the temperature and time determined for each food and consists of dipping the product in boiling water and later in cold water for cooling. Among other functions, this method inactivates enzymes, reduces the number of microorganisms on the surface of the product, favors color fixation and improves the sensory characteristics of food.

The main organic acid used is citric acid, which has the function of decreasing the Ph value, thereby providing an inhibitory effect on enzymes that promote food deterioration (Jesus et al., 2008).

Nevertheless, although the minimal processing of cassava roots offers numerous advantages for consumers as well as producers, there are still some problems, such as the lack of knowledge and planning of rural producers to insert this technology in their production and thus offer a food with better quality, value aggregation and greater revenue generation along the chain (Sanches et al., 2017).

The understanding by producers and companies about customer needs is often intuitive, thus being necessary, the use of a team to evaluate the selection of raw material, the quality of processing, the quality of texture, flavor and among other aspects, to verify whether the specific objective of each analysis was achieved (Teixeira, 2009).

The aim of this study is to determine the characteristics of minimally processed cassava, to present the methods of treatment and production of cassava minimally processed to increase the participation of cassava in the market of minimally processed meat.

2. Methodology

The systematic literature review was carried out, between June/2019 and February/2020, through the journal portal Capes and BVCA (Virtual Library Sciences Agrárias) using advanced research with the combination of the descriptors “agro-economic characteristics” and “minimum processing of the cassava”. These databases and digital libraries were chosen because they are a reference for many Brazilian researchers, concentrating well-qualified journals nationally and internationally.

The selection of articles was based on the following criteria: national and international publications that responded to the advanced search, without restriction of time period, with a view to understanding the historicity of research on this subject. It is noteworthy that, despite the lack of time restriction, all articles found fell within the range of publications carried out between the years 2002 and 2021.

At the BVCA, with the advanced search for the descriptors “agro-economic characteristics” and “minimal cassava processing”, 20 national and international publications were initially listed. In the CAPES portal, in the advanced search, 26 articles were identified.

3. Relevant Aspects of Cassava Culture

Cassava *(Manihot esculenta* Crantz) (Figure 1a), a species originally from Brazil, belonging to the class of dichotystone, has tuberous roots rich in starch, belonging to the family Euphorbiaceae, genus *Manihot* composed basically of

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98 species. It is distributed mainly on the continents, American, African, and Asian. In Brazil, it has well-defined socioeconomic importance because the large amount of starch from its roots guarantees the food security of families with low purchasing power, due to its versatility of use, besides providing income to small farmers who supply the local market in their region (Vieira; Fialho; Silva, 2013).

About 87% of cassava production in Brazil comes from family farms, and these producing units basically use manivas-seeds (Figure 1b) produced on the property itself for planting, less than 5% of these producers use agricultural pesticides in their crops and only 12% use mineral fertilizers. In addition, the cycle of this crop can occur annually where the harvest occurs between 8 and 12 months after planting, and perennial where the harvest takes place between 14 and 24 months after planting (Aguiar, 2013).

Figure 1 - Planting cassava (a) and manivas - cassava plant seeds (b).

(a) (b)

Source: Portal agropecuário (2012); Brazil (2013).

The cassava root system is composed of fibrous roots and tuberous roots (LI et al., 2010). The former has the function of absorbing water and salts, as well as serving as support support. In addition, some of these roots through the process of cell division and cell differentiation give rise to tuberous roots. These, in turn, are responsible for the accumulation of reserve substances, especially starch. Thus, these roots add nutritional value, because they combine high energy levels with vitamins, minerals and dietary fiber, but have low protein content in their composition, between 1% to 2% (LI et al., 2010).

According to the Food and Agriculture Organization of the United Nations (FAO, 2013), mandioculture is carried out mainly by smallholder farmers in more than 100 countries in the tropics. Because it has roots rich in carbohydrates and leaves with up to 25% crude protein, it has become a great caloric source in both human and animal food. According to Aguiar et al., (2013), starch is one of the main nutritional components of this plant, and can be used in the food industry, pharmaceutical products, as well as for the manufacture of plywood and bioethanol, the organization points out. Starch is the raw material for the emergence of various products such as chocolate, milk powder, sausages, candies, biscuits, packaging, among others, and can be used for these purposes in fermented, modified or "in natura" form (Aguiar et al., 2013).

The shoot is an important food source for ruminants, although it has a higher amount of cyanogenic glycosides than the roots even in the meek varieties, they can be bitten and slowly dry to be supplied as silage and hay (Valle, 2007).

Cassava varieties can be classified as their destination as well as because of the hydrocyanic acid content. When the hydrocyanic acid (HCN) content exceeds 100mg kg^{-1} cassava, they are called bravas and intended for processing to be consumed mainly in the form of flour, starch and glucose. Manioc, table or macaxeira that is consumed preferably "in natura", fried and cooked, as well as, are destined to the industry for processing, has HCN content smaller than 100mg kg^{-1} of cassava (Vieira; Fialho; Silva, 2013).

According to Furtado et al., (2007), the formation of HCN occurs from the hydrolysis of cyanogenic glycosides, especially linamarin, which in addition to forming cyanide ion, also gives rise to D-glycopyranose and propane. There are several factors that can influence the concentration of glycosides among cultivars, among them, genetic, environmental, soil type, location, time of year, which may result in the concentration of up to 2000 mg kg^{-1} in tubers, as well as in leaves.

Oliveira et al. (2012), highlight that nitrogen fertilization and harvest time can influence the HCN content in plant parts. When N doses were between 219 and 241 kg ha^{-1}, there were higher accumulations of HCN (401 mg kg^{-1}) in the cortex, and lower accumulation (332 mg kg^{-1}) in the root pulp. It was also observed that for each kg of nitrogen applied in cover, the root pulp produced 0.56 mg kg^{-1}, the leaf 0.42 mg kg^{-1}, the stem 0.38 mg kg^{-1} and the cortex 0.34 mg kg^{-1}, indicating that the root pulp produces more HCN than the other parts of the plant. Moreover, plants at 90 days after planting (DAP) presented with high clarity, than those plants that were harvested at 360 DAP.

In addition to the low concentration of HCN, there are some other important features that should be considered to classify a good variety of cassava, such as possessbrown root film color, high starch content in roots, resistance to diseases and pests, small distance between knots in branches, pleasant taste, reduced cooking time, root pulp quality and yellow coloring , in addition to low fiber content in the roots (Fialho et al., 2013).

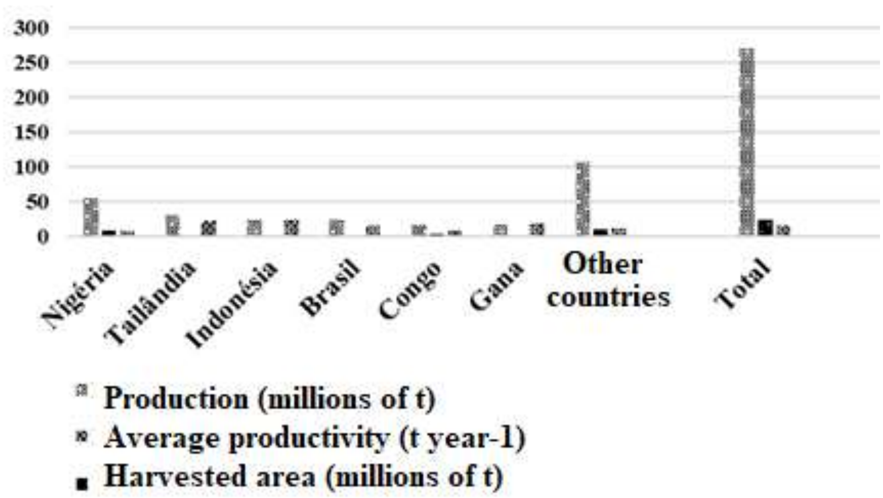
4. Production of Cassava Roots

4.1 World Production

In view of the large population of seven billion and two hundred million inhabitants, it is increasingly necessary to accelerate food production, especially those considered basic necessities of low-income families, such as rice, beans, corn, wheat and cassava (Seab, 2017). In relation to cassava, the African continent, for example, accounts for 50% of world production. In this sense, the period between 2010 and 2014 in which the greatest growth in the production of this food occurred, with an increase of 13%, from 243 million to 270 million tons of root.

According to the survey of the Food and Agriculture Organization of the United Nations (Fao, 2013), as cited by the National Supply Company (Conab, 2017), root production in 2014 reached 270.28 million tons.

Figure 2 - World cassava production in 2014.



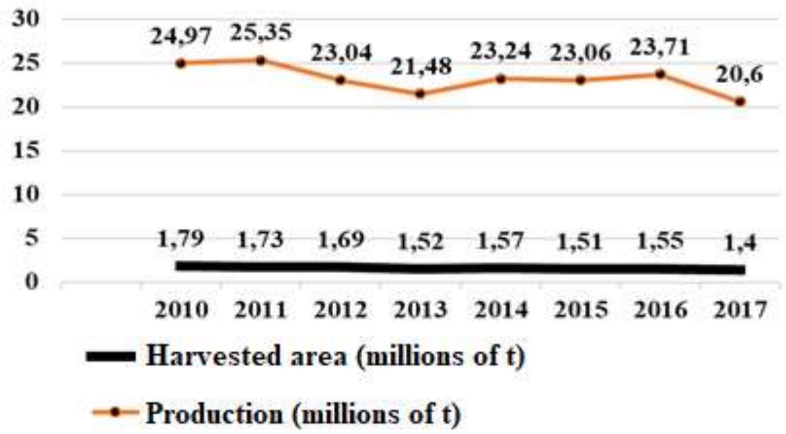
Source: National Supply Company - CONAB (2017).

Figure 2 shows Nigeria as the largest root producer in the world, with production equivalent to 54.83 million tons. Brazil is the fourth largest producer, with 23.24 million tons and together with Nigeria, Thailand, Indonesia, Congo and Ghana, they account for more than 60% of the world's cassava production (CONAB, 2017). Mandioculture has become an extremely important practice on the African continent, since of the twenty largest producers of cassava roots on the planet, twelve are from this continent. Between 2012 and 2016, Nigeria and Ghana grew by 12 and 22%, respectively. In relation to the production model of these countries, Thailand, for example, has lower operating costs than The Brazilians and receives government subsidies for export. Nigeria, on the other hand, has its production focused on supply mainly from the internal market (COÊLHO, 2018).

4.2 National Production

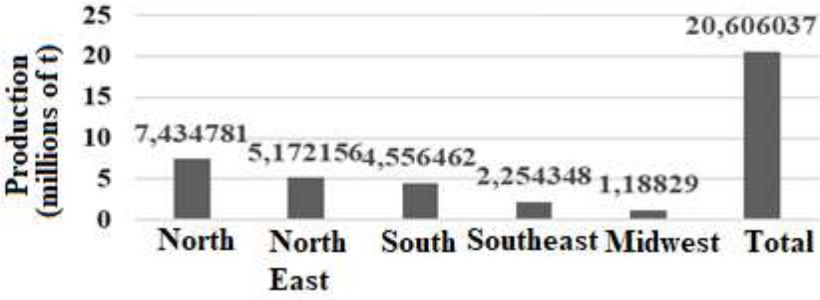
Cassava cultivation is carried out throughout the national territory. Ibge data (2017) show that Brazilian production from scratch, presented in the 2017 harvest with the worst rates since 2010, with a reduction of more than 11% in production, when compared to the 2016 harvest. Among other factors, the reduction of the planted area observed in some states was the main issue of emphasis for the occurrence of this problem. According to Alves, Felipe and Pereira (2017), root rot due to excessive rain, negative profitability that generated indebtedness in farmers and lack of manivas for new plantations, reduced the producer's interest in mandioculture, causing the reduction of the planted area in South Central Brazil.

Figure 3 - Cassava area and production between 2010 and 2017.



Source: IBGE - Municipal Agricultural Production (2017).

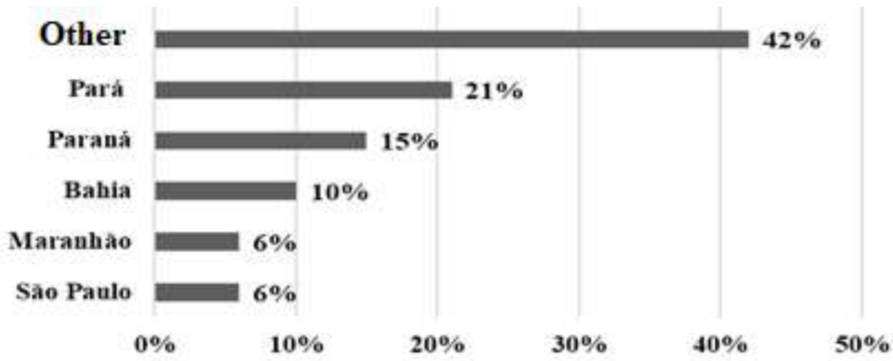
Figure 4 - Cassava production in the Brazil 2017 harvest.



Source: IBGE – 2018.

In regional terms, figure 4 shows that the North leads cassava production with a production share of more than 38%, followed by the Northeast region. These two regions together collaborate with more than 50% of national production. Within the Northeast region, the states of Bahia with 2.08 million tons and Maranhão with a harvest of 1.31 million tons of root stands out (IBGE, 2017). Paraná is the largest highlight of the southern region, as well as the largest producer of cassava in Brazil for industrial processing, showed production of 3.05 million tons in 2017. The importance of this State is emphasized, since the 2016 harvest was higher by 26%, compared to 2017. It is inferthat the lack of labor combined with the increase in the cultivation of other crops, were the issues that contributed to the reduction of this productivity (Conab, 2017).

Figure 5 - Participation of the main producing states in Brazil in 2017.



Source: IBGE - systematic survey (2017).

4.3 State Production

In production issues, Pará emerged as the largest producing state in Brazil. According to IBGE (2017), the Pará harvest reached 4.23 million tons from scratch. Although the use of cassava is considered versatile, it is observed that much of the production of Pará is focused on the manufacture of flour, which always occurs in a handmade way and for subsistence, because it is considered one of the items that are part of the food of paraenses. In addition, it is observed that the profile of cassava producers in Pará is composed of a large number of small farmers, as well as the presence of small agroindustries of tapioca flour and cassava flour, spread basically throughout the territory of Pará (Silva et al., 2014).

The state of Pará has 60.66% of the cultivated areas and consequently accounts for 56.96% of the production in the northern region. Thus, it presents the most producing municipalities and with the largest areas of Brazil, highlighting the municipality of Acará with 356,000 t, Santarém with 217,700 t, Oriximiná with 192,000 t, Alenquer with 170,000 t and Óbidos with 144,000 t, in 2017. For the same year, the municipality of Parauapebas had a production of 45,800 t, ranking 22nd in the ranking of the largest cassava producers (Fernandes, 2017). However, the same author points out that the efficiency of Pará is much lower than expected, since its productivity of 14 t ha^{-1} is lower than the national average. In addition, according to Aguiar et al. (2013), some municipalities in the state of São Paulo and Minas Gerais already achieve productivity of 40 t ha^{-1}.

5. Cassava Root Perishability

When compared with other basic food crops, the cassava root is outnumbered in a matter of perishability. Shelf life is one of the obstacles to increasing "fresh" consumption, and this is totally dependent on harvesting practices and storage conditions. Once mechanical damage occurs during harvest, they appear on broken or cut surfaces, geometric deformations, and the stored starch undergoes textural and structural modifications (Djabou et al., 2017).

According to Ramos et al. (2013), the deterioration of cassava root begins within the first 48 hours after harvest, resulting in the initial formation of bluish striae, discoloration of conductive vessels and darkening of parenchymatic tissues. The darkening of the roots occurs when polyphenoloxidade comes into contact with oxygen, in the face of physical injury, oxidizing phenolic compounds, where the product of this reaction is water and quinone. Quinone condenses, and in the polymerization reaction, catalyzes melanin, resulting in foreign odors, darkening of the vegetable and lignification of the cell wall (Santos et al., 2012).

When stored under environmental conditions, the large amount of water present in the root, more than 60%, facilitates the process of microbiological contamination, influencing the putrefaction of the root. This deterioration occurs basically in two ways, one physiological when the action of enzymes on carbohydrates occurs, causing the sagging of the pulp. The other is microbial, which is due to the activity of pathogens such as fungi and bacteria, intensifying the fermentation process and rotting cassava with the appearance of molds (HENRIQUE; PRATI, 2011).

Freire et al. (2014) highlight the minimum processing as a viable alternative for the commercialization of cassava roots, since this technique allows an increase in storage time, reduction of perishability and increases the shelf life of the postharvest root.

6. Minimum Cassava Processing

Certainly, products that facilitate the preparation and consumption are increasingly entering the purchase list of Brazilians. Among other qualities, these products should offer practicality, freshness, reduction of the consumer's labor, good appearance, besides maintaining nutritional and sensory characteristics, as well as guarantee of sanity (DURIGAN, 2007). Given the nutritional policies, the growing search for trying to insert healthier foods into the diet, aiming mainly at ingesting the essential elements for the proper functioning of the body, it is verified that fruits and vegetables have become the great attractions to meet this demand, making the market for these products in recent years have an expressive leap, especially when they are in conditions of minimally processed foods (Nascimento et al., 2014).

In this sense, it is verified that the acceptability of cassava roots "in natura" by consumers is increasingly lower since the visual aspect, high post-harvest deterioration, cooking and variable size, little practicality in the use and preparation, as well as the lack of product information to the consumer, are the main obstacles to the reduction of consumption "in natura". Thus, it is evident that the table cassava root has great market potential among minimally processed foods (Figure 6) (Rinaldi et al., 2010).

Figure 6 - Minimally processed cassava.

Source: Authors.

A minimal processing technique with an innovative format will cause reduction of postharvest physiological changes, increase in cassava consumption and consequently improvements to root agribusiness (Junqueira, 2009). Thus, Freire et al. (2014) emphasize that the minimal processing of manioc manioc in minitolete and rubiene formats can function as great alternatives for the growth of cassava consumption.

Minimal processing has become a great alternative for the consumption of fresh products, due to practicality, high convenience and mainly free of microbiological contamination (Iuamoto et al., 2015). Among the objective of solving the post-harvest problems, as well as, to make the producer able to offera product of higher quality and with a better price, cassava can be submitted to processing through various forms, such as minimal processing, peeling, and cooling, frozen raw, frozen after and sterile, and vacuum packed and fried (Rinaldi, 2013).

Minimally processed roots are submitted to the following steps: selection of pathogen-free roots, washing in running water, peeling of the external and internal film, cutting into smaller sizes for standardization, chlorine sanitization, drying, packaging and storage. Although its physical characteristics are altered, the product must still be able to present itself in conditions of freshness like the product "in natura" (SANTOS et al., 2010). The characteristic of fresh product can be achieved by applying techniques such as cooling or freezing, bleaching at moderate temperature, packaging in modified atmosphere and use of natural antimicrobial systems (Santos; Oliveira, 2012).

The process of washing in running water, peeling, and cutting, are important steps in the process because it aims to promote the light removal of the microbial load that are adhered to the roots, since they were in contact with the soil. However, they should be done with caution to cause minimal physical wear to the product (Henrique; Prati, 2011). Cell disruption during peeling and cutting causes the interaction between enzymes and their substrates, resulting in accelerated biochemical reactions that alter the nutritional and sensory qualities of the product (Durigan, 2007).

Another factor to be considered in the washing stage of minimally processed cassava is the quality of water because the use of contaminated water can certainly function as a vector of undesirable microorganisms, thus hindering all subsequent procedures, resulting in an unfeasible product for consumption. In addition, disinfection is essential to ensure the microbiological reduction of the product because these organisms can, among other issues, cause their consumers food poisoning. Chlorine-based chemical disinfection is the most widely used in the food industry as they are good antibacterials and, if used in the proper concentrations the product leaves no unpleasant flavors or odors. Among the chlorine compounds, the most common are calcium and sodium hypochlorites (Silva et al., 2014).

Certainly, packaging is the fundamental stage of minimal processing, and its role is distributed throughout the chain, from the producer to the consumer. Therefore, the ease of handling the product during storage and distribution, maintenance of the nutritional and sensory characteristics of the product and guarantee of conservation, are inherent functions of packaging. In addition, given environmental issues, more demanding consumers and the search for the best cost-benefit, packaging technology is one of the fastest growing sectors worldwide (Santos and Oliveira, 2012).

The type of packaging for minimally processed products is associated with the permeability of the packaging to oxygen, carbon dioxide and ethylene gases and water vapor, product weight, space occupied by the product inside the package, degree of maturation, variety and size of the product, the environment, light, mechanical stress, among others. However, the most recommended films for packaging of minimally processed foods are: polyethylenes with different densities, vinyl polychloride (PVC) with different levels of plasticizer thicknesses, ethylene vinyl acetate (EVA) with different contents of vinyl acetate, polystyrene (PS) including polyolefinics, microperforated and bioriented polypropylene (BOPP).

Evaluating an active film of polychloride vinyl (PVC), Rauschkolb et al. (2017) conclude that up to 12 days of analysis at 8°C, there was maintenance of the good appearance of the product, in addition to the microbiological and sensory quality. According to Araújo et al. (2010), staketray slanded with PVC and polypropylene (PP) packaging, are efficient to maintain the quality of cassava root minimally processed for 18 days.

Correct storage of cassava at adequate temperature is an essential factor in the process. The previous steps reduce the microbial load, however, do not make cassava sterile, that is, phytosanitary problems can occur more quickly if there is no control and maintenance of the strict refrigeration temperature (Santos; Oliveira, 2012). Refrigeration works in delaying moisture loss, maintaining the nutritional and sensory qualities of the product, minimizing mechanical damage caused in previous steps, reducing contamination by pathogens, and consequently reducing physiological changes (Nascimento et al., 2014). According to Henrique and Prati (2011) root deterioration after processing can be reduced if it is maintained in cooling close to 5°C.

Sanches et al. (2017) studying the sensory and economic viability of frozen cassava, concluded that freezing does not alter the organoleptic qualities of the root, as well as more than 70% of the interviewees answered that they would certainly buy frozen cassava.

The freezing of pre-processed cassava at -18°C can act as an important factor to reduce the activity of microorganisms and possible deterioration, significantly prolonging the possibility of root consumption by up to 150 days, without significant sensory loss of the product (Carvalho et al., 2011). According to Rinaldi et al. (2015) the temperature of – 18°C keeps cassava with sensory quality for at least 30 days.

Silva et al. (2003) report that cassava minimally processed when stocked at 25°C did not exceed the sixth day of storage, presenting with darkening, fermented and exudation of liquids. However, when stored at 10 °C the roots became viable within 12 days.

Consequently, it is believed that the development of minimally processed cassava is a viable alternative to increase the participation of roots in the consumer market, as well as to provide consumers with a product with quality, practicality, economy, and nutritional value. In addition, it provides smallholder farmers with the possibility to add value to the product sold and increase family income.

7. Conclusion

Cassava is a highly profitable crop and has good production in cultivation systems.

Cassava presents favorable aspects and characteristics for the production of products and by-products.

Minimally processed cassava is a product that has good viability because it has excellent nutritional quality. This product is appreciated both nationally and internationally because it has unique characteristics of flavor and aroma.

The production of minimally processed cassava is one of the alternatives to increase the income of producers due to low nutritional requirement and water availability, besides being a culture of easy adaptability in several states of the country.

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