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OSMOTIC DEHYDRATION WITH COMPLEMENTARY DRYING AS A SOCIAL TECHNOLOGY: USE OF BANANAS OUT OF THE STANDARD FROM CV. GRANDE NAINE.

Desidratação osmótica com secagem complementar como tecnologia social: Uso de bananas fora de padrão cv Grande naine.

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RESUMO: A desidratação osmótica é técnica simples aplicável a frutas e hortaliças. Permite aproveitar matérias-primas, reduzir perdas e agregar valor. Bananas fora de padrão da cv Grande Naine foram processadas sob três critérios de boas práticas de fabricação (BPF) e as passas acompanhadas por 180 dias apresentaram estabilidade e qualidade, independente do tipo de BPF, o que permite sua recomendação.

Palavras-chave: Mercado, Qualidade, Boas Práticas de Fabricação, Microbiologia de alimentos, Segurança dos alimentos.

ABSTRACT: Osmotic dehydration is a simple technique suitable to fruits and vegetables. It allows taking advantage of raw materials, reducing losses and adding value to the product. Bananas out of standard from the cv. Grande Naine were processed under three levels of good manufacturing practices (GMP) and the raisins assessed for 180 days presented stability and quality, regardless of the type of GMP, which allows their recommendation.

Key words: Market, Quality, Good Manufacturing Practices, Food Microbiology, Food Safety.

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INTRODUCTION

Brazil is the world`s third largest fruit producer, an agricultural activity that achieves significant results and generates opportunities for small Brazilian businesses. The national fruit production exceeded 40 million tonnes in 2013, and among all the tropical fruits, banana (*Musa* spp.) is the most consumed in the world. In Brazil more than 95% of its production is assigned to the domestic market, representing a *per capita* consumption of 25 kg per year (JAIGOBIND et al., 2007; SEBRAE, 2015; EMBRAPA, 2018).

Fruticulture, an activity with great economic potential, suffers, however, losses and wastes of production that exceeds 40 to 50%. These losses affect the availability of food for consumption at all stages, from production to post-harvesting, storage, and transportation. The waste is related to food waste losses that still have value, what is mainly associated with the sellers behaviour, services and consumers (FAO, 2018). Hence, the losses reduction can be considered as a production increase, with the possibility of valorising the raw material and consumption optimization.

Traditionally, in techniques of osmotic dehydration, partial dewatering and direct formulation of food products can be obtained by their immersion in concentrated solutions. This process, also known as dewatering and impregnation soaking process (DIS process), can be used as a pretreatment before any complementary processing and may lead to energy savings and quality improvement. Currently, industrial applications of this process have mainly been limited to semi-candied fruit production lines, which control has mostly been empirical. Advances in the control of mass transfer have opened up the way for the process optimization and the development of new applications, which have, in turn, triggered off new research areas. These are mainly related to the management of concentrated solutions and the microbiological validation of the process (RAOULT-WACK, 1994).

According to Torreggiani (1993), the basic principles which control osmotic dehydration of fruit and vegetables are reported with the most important parameters and their influence on the process. The effects of osmosis as a pre-treatment are associated mainly to the improvement of nutritional, sensorial and functional properties of the products. The distinctive aspect of this process, when compared to other dehydration methods, is the direct formulation achievable by the selective incorporation of solutes, without modifying the food integrity. Hence, by balancing the two main osmotic effects, water loss and soluble solids uptake, the functional properties of fruit and vegetables could be adapted to many different food systems. On the other hand, water activity (aw) is a reliable indicator of the status of the osmotic solution, since it is strictly related to the dewatering capacity of the solution. In fact, the osmotic dehydration proceeds until the osmotic solution and the food product have reached the same aw value (BARBOSA-CANOVAS and VEGA-MERCADO, 1996).

Osmotic dehydration (OD) is an important operation used to transform perishable plant-origin foods into new value-added products with longer shelf life. This process is responsible for the removal of water when fruits and vegetables are immersed in a hypertonic solution with high osmotic pressure (EGEA & LOBATO, 2014).

The main advantages of OD are the inhibition of enzymatic browning, retention of natural color, retention of volatile compounds with low energy consumption, and better preservation of the nutritional value. For the application of this technology, sucrose is considered as a good osmotic agent, especially when OD is used as a preliminary step to drying, as it prevents enzymatic browning and aroma loss (CRUZ et al. & LOBATO, 2014).

OD is a simple process that allows better use of the excessively ripe fruits which are still in the field. In addition to requiring low investment, it guarantees products with proper texture, colour, and flavor. The application of OD, prior to the processes of artificial and natural dehydration, results in a reduction in time and energy expenditure (SOUSA et al., 2003; GOMES, VILPOUX and CEREDA, 2007). However, according to Warczok et al. (2007), the main concern when using osmotic dehydration in fruits and vegetables is the necessity to modify this technique from a laboratory procedure to a continuous industrial level. In this case, it becomes more difficult to monitor the state of the hypertonic solutions by the water activity (aw) measure that should be no higher than 6.0.

The drying of fruit allows reducing losses in the most diverse agro-industrial segments. In addition to that, using technological innovation for integral fruit utilization results in products with higher profitability and viability. In the model of sustainable economic development, designed for small family farmers, a simple and practical technological innovation allows the production of cereal bars, jellies, and sweets (PANNIRSELVAM et al., 2015; SILVA et al., 2017).

Considering the scenario of sustainability, it is important to apply eco-efficient methodologies in the elaboration of new products, as well as the possibility of using them by small producers. Some researchers propose projects in this sense, helping to overcome the needs of local communities, as well as training multipliers in the food technology area with the knowledge to develop nutritional products, which will be generated through the use of science and technology (PANNIRSELVAM et al., 2015). In addition, the production of food that is safe from a sanitary and physicochemical point of view guarantees the manufacturer a prominence in the market value.

The stability of the products subjected to dehydration by osmotic pre-treatment, followed by drying in an oven, does not discharge from an adequate hygienic-sanitary condition processing method, even on a small scale. Good manufacturing practices (GMP) are quality standards applied in the preparation of new products in order to guarantee the market a product without contamination risks. Hence, GMPs are indicated so that these products are consumed without any additional preparation and so that they can be conserved for a longer period of time without causing problems to the consumers` health (Martins et al., 2012; Batista & Borges, 2013; DURIGAN et al., 2014).

Considering the relevant sustainability of the integral raw-material use in obtaining new food with quality to the consumer market, it is important to evaluate the influence of good manufacturing practices on the microbial and physicochemical quality of raisins obtained by osmotic dehydration, since the literature presents little information on the subject. The purpose of the present work was to evaluate for 180 days the physicochemical and microbial parameters of banana raisins obtained by OD, in a process that used three criteria (levels) of good manufacturing practices (GMP).

MATERIAL AND METHODS

Selection and storage of the raw material: The experiment was conducted from the spring to the summer season, which corresponds to the period from August to January in the Brazilian Central-West Region.

Bunches of banana from the Grande Naine cultivar organically cultivated at the geographic coordinates 20º26'34" S and 54º38'47" W, at 532 meters altitude, were harvested. The fruits were harvested in the green stage (not ripe fruits), divided into lots and stored in a closed room, with partial ventilation and at room temperature varying between 20 and 35° C. After continued maturation, the bananas presented a classification corresponding to categories II and III (variable and severe imperfections) according to the General Warehouses and Company of Warehouses of São Paulo (Companhia de Entrepostos e Armazéns Gerais de São Paulo – CEAGESP, 2006). In the usual fruit market, this raw-material would be discarded in the consumer market of fruits *in natura* due to their classification.

Application of Good Manufacturing Practices (GMP): Each lot was submitted to small GMP variations, as follows: Lot 1 - Minimum Treatment: cleaning of the work table with a damp cloth in water, handwashing with neutral liquid soap, followed by disinfection with alcohol 70%, manual peeling of fruits, followed by manual cutting of fruits using stainless steel household knife, sliced approximately 0,50 cm thick and 7,0 cm long. Lot 2 - Medium Treatment: cleaning of the work table with a damp cloth in water, handwashing with neutral liquid soap, followed by disinfection with 70% alcohol, manual peeling of the fruit, new handwashing, manual cutting of the fruit with the same characteristics of Lot 1 using disposable procedure gloves. Lot 3 - Ideal Treatment: cleaning of the table and all utensils with alcohol 70%, disinfection with sodium hypochlorite solution 200ppm, followed by manual peeling, new handwashing, manual cutting of fruits following the same steps of Lot 1, using disposable procedure gloves.

Osmotic dehydration: The drained banana cuts were weighed according to the pre-established lots and placed in white polypropylene trays (30.0 x 20.0 x 6.0 cm) where they received commercial sucrose in a weight corresponding to 10% of fruit weight, spread directly on the surface of the cuts. The osmotic dehydration occurred for 4 hours at room temperature, after which the slices were drained from the syrup formed and subjected to a complementary to drying in an oven with air circulation at 55-60ºC for 30-40 hours, as established by Gomes, Vilpoux and Cereda, (2007). The bananas raisins prepared were fractionated in sub-samples of 50 ± 0.05 g, which were manually packed in polyvinyl chloride (PVC) films, of 10 µm of thickness and density of 1,400 kg/m^3, for food.

Storage: Storage was carried out in a ventilated room, without direct sunlight, which provided room temperature varying from 25ºC to 30ºC. The temperature and humidity were monitored with an Incoterm® digital thermo-hygrometer during the 180 days of the experiment.

Quality control: the quality of the banana raisins was monthly monitored by microbial content and variation of the physicochemical analyzes in randomized samples, taken immediately after processing until the end of the experiment.

Microbial analysis: the analysis of the microbial quality investigated the total heterotrophic bacteria, total and thermotolerant coliforms, *Escherichia coli*, *Salmonella* sp., *Bacillus cereus*, *Staphylococcus aureus*, molds and total yeasts, and thermoresistant spores (APHA, 2001).

Physicochemical analyzes: the analyses of moisture content, volatile compounds at 105ºC, and acidity in normal solution were performed in triplicate, during storage (BRASIL, 2005).

Data Analysis: the results of the physicochemical characteristics were submitted to the analysis of variance and the averages were compared by Tukey test at 5% of probability and compared to the standards of the current legislation. Correlation tests were performed according to Pearson's correlation to 5 % probability ($\alpha = 0.05$) using the software Statistic 13.2 (2017).

RESULTS AND DISCUSSION

The selection of bananas cv Grande Naine which simulated the advanced maturation stage, with objectionable characteristics by the consumer market, showed that although they presented bad exterior appearance, they had characteristics compatible with what is expected by the consumer in the inner tissue once removed the peel, without spots or changes in texture, what justifies its use in order to avoid waste. This information even passed on to the producer, would not prevent rejection if commercialization were made with fresh fruits. The processing of these fruits had, therefore, the purpose of optimizing the possibilities of commercialization of this refuse.

Regarding the initial weight of the selected fruits, they yielded about 75% of pulp after peeling, which after osmotic dehydration and complementary drying corresponded to about 20% of banana raisins. The final product was banana raisins, which, regardless of the good practice's treatment applied, showed good visual appearance, clear and shiny. As for the processing time, it was established that the bananas raisins could be considered ready to go to market in less time than 48 hours, counted from the beginning of the process, presenting a golden color, different from the dark color of the local commercial bananas.

The banana slices were then packed to simulate the storage life in the countryside. The choice of transparent stretchable films selected for the raisins confirmed its suitability, agreeing to Barão (2011) and Jorge (2013), who recommend it mainly because of its low cost, ease handling and attractiveness of the product, in addition, to contributing to the maintenance of the social technology characteristic.

The storage of the dehydrated bananas tried to simulate the reality of the rural environment. The monitoring showed an average temperature of 28.2 ± 3.8ºC, with a mean air humidity of 63.6 ± 11.7%, ranging from a minimum of 37% to a maximum of 84%.

Microbial aspects: the monitoring assessment of the stored raisins are presented in Table 1.

Table 1 – Assessment of total heterotrophic bacteria, total molds and yeast in colony forming unit per gram (CFU / g) found in osmotically-dehydrated bananas with complementary drying in an oven, submitted to good manufacturing practices, during 180 days of storage at room temperature.

	Total heterotrophic bacteria			Total molds and yeast		
	Good manufacturing practices levels					
Days	**Minimal**	**Medium**	**Ideal**	**Minimal**	**Medium**	**Ideal**
1	120	100	60	190	20	25
30	300	90	1	50	10	2
60	200	20	1	20	2	1
90	40	3	1	1	1	1
120	10	30	1	1	1	1
150	20	1	1	3	1	1
180	10	1	1	1	1	1

It is highlighted that, despite the application of the osmotic dehydration technique, the amounts of *Salmonella* sp., coliforms, *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus cereus* were null in the samples, regardless of the GMP treatments used. Total spore contamination was <1UFC/g for all treatments at all the evaluated periods.

It can be affirmed that by the norms for human consumption, all levels of Good Manufacturing Practices led to the achievement of raisins with adequate microbial characteristics. The current sanitary legislation establishes the maximum of 10^2 NMP/g for Coliforms at 45 ºC, and the absence in 25g for *Salmonella* sp., for dehydrated fruits (BRASIL, 2001).

The graphs in Figure 1 show that the amounts obtained for growth of heterotrophic bacteria only decreased with the storage time from an initial of 1.2 $x10^2$ CFU/g to practically stabilize at 1x10 CFU/g at 180 days within the minimum treatment, as well as it happened with yeast and molds amounts, which declined from an initial number of $1.9x10^2$ UFC/g to near null values.

The stabilization of mold and yeast amounts was observed regardless of the treatment used (Figure 1). For this group of microorganisms, it cannot be affirmed that the Good Practices adopted influenced the raisins quality in function of storage time. Similar results of low amount count of microorganisms are cited by Batista et al. (2014) who evaluated the shelf life of banana raisins obtained by drying at 65 °C and packed in cellophane paper. After 180 days, the results indicated that yeast and molds counts were below 10 CFU g^{-1}, with the absence of coliform and *Salmonella* sp growth at 45 °C.

Regarding the moisture content at 105ºC and storage time, significant differences were observed between them, independent of the level of Good Practices applied. The moisture content obtained by the raisins produced through the Medium treatment of Good Practices differed from the others after the 120th day (Table 2)

Figure 1 – Adjusted curves for total heterotrophic bacteria and total molds and yeast counts found in banana raisins produced through osmotic dehydration and three levels of Good Manufacturing Practices and stored at room temperature for 180 days.

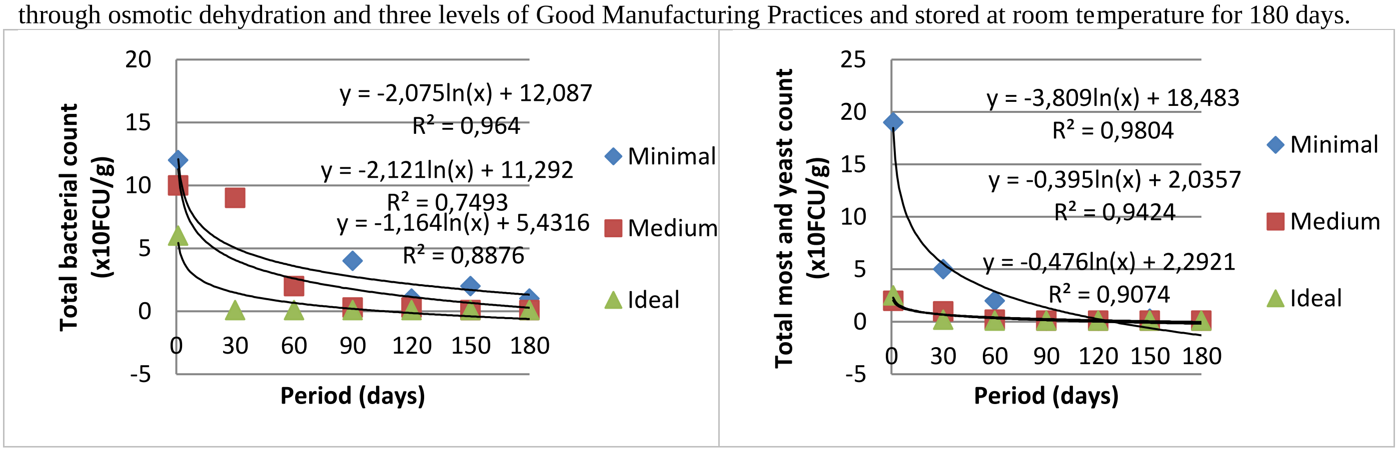

Table 2 – Variation of moisture and volatile contents at 105ºC, and acidity in normal solution (%) of osmotically dehydrated bananas with complementary oven drying, submitted to good manufacturing practices and stored at room temperature for 180 days (mean of 3 replicates).

Days	Humidity and volatile at 105ºC			Acidity in normal solution		
	Good manufacturing practices levels					
	Minimal	Medium	Ideal	Minimal	Medium	Ideal
1	33,63 Ac	31,89 Bd	34,71 Ac	3,1 Ab	2,7 Bc	3,0 Aa
30	34,13 Bb	32,88 Bb	35,61 Aa	3,0 Ac	2,6 Bd	3,0 Aa
60	34,71 Aa	33,28 Bb	35,19 Ab	3,1 Ab	2,7 Bc	2,5 Bb
90	34,10 Bb	33,58 Ba	35,27 Aa	3,2 Aa	2,8 Ab	2,4 Bb
120	34,83 Aa	34,20 Ba	35,28 Aa	3,0 Ac	2,9 Aa	2,5 Bb
150	35,10 Aa	32,08 Bc	34,21 Ad	3,2 Aa	3,0 Aa	2,4 Bb
180	34,00 Ab	31,89 Bd	35,61 Aa	3,1 Ab	2,8 Bb	2,5 Bb

Note: Means followed by the same uppercase letter in the line (for each parameter) and lowercase in the column, do not differ by Tukey test at 5% of probability.

The differences between the moisture contents may be related to the packaging and to the relative air humidity, which may be explained by the influence of the packaging permeability to water vapours during storage. The polyvinyl chloride (PVC) film presents as general characteristics: easy processing, good gas barrier and poor water vapor barrier, and its permeability depends on the plastification degree - when much plasticized it is indicated for fresh meat and fruits, due to the high oxygen permeability (BARÃO, 2011; JORGE, 2013). Similar results were observed in a study of passion fruit shelf life before the sanitization and refrigeration, where there was no linear reduction of fruit acidity during storage. In this work, the authors state that the use of sanitizers does not increase fruit shelf life (RINALDI et al., 2017).

Acidity variations in dehydrated products may occur during storage. Researchers suggest that, in addition to possible physicochemical changes that occur over time with the removal of part of the free water, the acids presented on the fruit tend to concentrate, increasing the acid levels of the fruit (MARTINS et al., 2012).

The acidity may also have contributed to preventing the initial microbial load from having ideal conditions for cell multiplication. Researchers who used OD for the processing of vegetable products attributed the stability found in the evaluation of the shelf life to the characteristics of the elaborated products, which had higher acidity and soluble solids indexes, increasing unfavorable conditions for the development of the majority of microorganisms. All these factors contribute to the conservation of the products from a microbiological point of view at room temperature (MARTINS et al., 2012).

The results of the physicochemical analyzes suggest the banana raisins stability, which was evidenced by the parameters moisture content and acidity. This study is supported by Batista et al. (2014), who found no acidity variation in banana raisins which had their moisture content reduced to 20 and 25% for 180 days. However, it cannot be affirmed that the criteria of Good Manufacturing Practices used in the present work directly influenced the physicochemical characteristics of the final product.

Considering the relationship between intrinsic and extrinsic factors in food preservation, it is important to continue the physiochemical study of the foods to determine the effect of failures in storage conditions, to predict the microbiological safety of a product, and to predict shelf life, as it is verified that the temperature can vary widely during the period of food storage and distribution, as opposed to pH and water activity that are more stable (OLIVEIRA et al., 2013).

Moisture content, water activity, pH and acidity are known to interfere with the viability of microbial growth. In the case of fruits, the alteration phenomena are initiated by molds, because they adapt to more severe conditions than most of the microorganisms, tolerating high concentrations of sugar and acids. The presence of moisture should be considered because fungi can only cause deterioration if the water activity is relatively high, which does not occur in dehydrated products (GUINEE et al., 2010). In this case, we obtained results that prove that the combination of osmotic dehydration and complementary oven drying, associated to the application of good manufacturing practices resulted in a product with low microbial load and safe throughout the storage period.

To ensure the safety and quality of plant products for a certain period of life, the sanitization is one of the most important points in the processing line. The hand hygiene (handwashing) procedure, the hygiene conditions of the place, manipulators and utensils influence the reduction of cross-contamination. Organic food is more susceptible to microbiological contamination due to the use of animal waste in fertilization, which may be contaminated by the bacteria of the coliform group (BATISTA et al., 2014; FARIAS et al., 2015; RODRIGUES et al., 2015).

Considering that the contaminating microbial species of fruits depend on the management and agricultural practices, the literature cites, in addition to fertilization, the use of contaminated irrigation water, increasing the possibility for contamination by *Salmonella*. Hence, for the efficiency of the disinfection process, it is necessary that the raw material presents a low contamination level since the sanitization processes are able to reduce, on average, 100 time folds the initial microbial amount (CARVALHO, 2010).

The adoption of OD in industrial production processes is hindered by problems with the overall management of the concentrated solutions. In fact, there are still some practical aspects that make managing and controlling the osmotic solution the bottleneck of the osmotic dehydration process. In particular, there are still some major concerns regarding the appropriate individuation of the loss in dewatering capacity and the possibility of re-using the spent solution, so as to make the process more economically advantageous (WARCZOK et al., 2007).

GMP applied in the production of dehydrated products was sufficient to reduce the number of viable microbial cells.

There was a better quality profile when the Medium Treatment of GMP was applied, that is, it is suggested that fruit processing should be performed using at least the hand hygiene (handwashing) criteria at each step change in the OD process, in addition to the use of procedure gloves. The results found in the present work, after the application of OD with the use of GMP, suggest the stability of banana raisins during the 180 days.

CONCLUSIONS

From the viewpoint of human consumption norms, it can be stated that the banana raisins obtained from the selection of non-standard bananas, subjected to osmotic dehydration and stabilized with a complementary drying, resulted in a safe food product according to the norms of the current Brazilian sanitary legislation, with the absence of *Salmonella* sp. and with the amounts of Coliforms at 45ºC within the required limits. The amounts of total heterotrophic bacteria, molds, and yeasts, as well as being within the norms at the initial moment, only decreased with storage time to the point of practically stabilizing from 90 to 180 days.

The product was considered to be pathogenically safe because of its non-contamination by *Salmonella* sp., Coliforms, *Escherichia coli*, *Staphylococcus aureus*, and *Bacillus cereus*, with small variations in relation to the appropriate GMP conditions and shelf life for raisins manually packed in polyvinyl chloride (PVC) films for food. In addition to presenting a microbial pattern compatible with dehydrated products for the market, the raisins presented good appearance and good shelf life when considering the variation in the physicochemical analyses, since the banana raisins presented stability in moisture content and acidity throughout the storage time, both when considering the ideal and the medium treatments of Good Manufacturing Practices.

The results allow to recommend the process of osmotic dehydration with a complementary oven drying and applying criteria of good manufacturing practices to reduce losses in the field and to produce a stable and safe food to the consumer market.

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