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Effect of Pretreatment and Osmotic Dehydration on the Quality and Technological Properties of Dried Banana (cv. Thap Maeo)

Natasha Veruska dos Santos Nina [a*], Jerusa de Souza Andrade [b], Suely de Souza Costa [b], Raimundo da Silva Souza [b] and Mirza Carla Normando Pereira [a]

[a] *Embrapa Western Amazon – EMBRAPA, Rod. AM-010 S/N, km. 29, Manaus, AM, Brazil, CEP: 69010-970, Brazil.*
[b] *National Institute for Amazonian Research – INPA, Av. André Araújo, 2.936 – Petrópolis – Manaus – AM. CEP 69067-375, Brazil.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The banana is a product to preserve banana, avoid post-harvest losses and add value. This study aims to evaluate pre-treatments of prevention enzymatic browning and osmotic dehydration, influence on drying time, proximate analysis, physicochemical characterization, color and yield in

**Corresponding author: Email: nina.natashavs@gmail.com;*

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bananas cv. Thap Maeo. The biometric characterization was performed. Bananas cv. Thap Maeo was submitted to pre-processing: antioxidant (acid ascorbic (0.25%), acid citric (0.30%)), bleaching (94°C), sulphitation ($Na_2S_2O_5$/0.01%), with and without osmotic dehydration in sucrose solution (65°Brix/6h) and oven dried (65°C). The obtained products were evaluated for drying curve, chemical composition, physicochemical characteristics, internal color and external color, and dried banana yield. The banana of cv. Thap Maeo presents big bunches, high number of fruits, class 12, medium fruits, moderately sweet, low acidity, pulp yield (80.47%) e 92.65 kcal). These technological properties are interesting for agribusiness. There are significant differences for prevention and enzymatic browning, osmotic dehydration and interaction for several evaluated parameters. Dried banana with osmotic dehydration dried in 32 h, dry matter (80.1%), carbohydrates (74%), TSS (65º Brix), TSS/TTA ratio (59.3), ash content (0.4%), lower Aw (0.59), moisture content (19.9%), lower texture (2.23 N), 312 Kcal. Bleaching was the best in preventing the enzymatic browning in dried banana, with lower values of crude fat (0.24%), DM (78.1%), texture (less hard, 2.43 N), low moisture content (21.9%), low pH (4.26), AW (0.66), high yield (39%). Color light, red and yellow: color external (L*(29.1), a*(10), b*(10.3)) and color internal (L*(38.9), a*(12.1), b*(19.9)). The dried banana blanched with osmotic dehydration can be an opportunity for agribusiness bananas, added value, and conservation bananas, and can serve as a basis for Local Productive Arrangements - APL's, in the Amazon. We recommend that further studies bleaching be carried in bananas with peel, steam blanching, immersion in liquid nitrogen, freeze cycles, and loss of minerals.

Keywords: Bleaching; color; dried banana yield; prevention of enzymatic browning; texture; water activity.

1. INTRODUCTION

The banana plant of cv. Thap Maeo is a variant of Mysore, genomic group AAB, Apple group. This cultivar was selected by Embrapa cassava & fruits and was distributed to producers by the Institute for Agricultural Development of the State of Amazonas - IDAM, to replace banana trees susceptible to diseases. The cv. Thap Maeo is resistant to black sigatoka and yellow sigatoka and Panama disease, moderately resistant to rhizome drill and nematodes (Pereira et al., 2000; Pereira et al., 1998). Also, it has high size, vegetative cycle of 394 days, big bunch, with Weight of 17 kg, Number of Hands per Bunch of 11, mean of Number of Fruits per Bunch of 164, and yield of 28 t/ha. Still has high productivity, high Pulp yield and good characteristics for processing (Oliveira et al., 2002; Jesus et al., 2004). Banana crops are very relevant for the agribusiness of the State of Amazonas, because the banana is part of the food base of the Amazonian population, with consumption per capita of 60 kg/year. However, losses can reach 40% of banana production because of inadequate techniques throughout the production chain, which compromise the quality of the product.

Another obstacle is the low *in natura* consumption of fruits of some varieties resistant to diseases that are grown in Amazonas (Pereira et al., 2000) which due to changes in flavor of these varieties, result in low acceptance. The application of techniques such as dehydration increases shelf life and can improve the acceptance of these bananas. Several methods of drying bananas are performed, such as solar dryers, hybrid methods and oven drying. Among the recent methods are handmade solar dryers with direct exposure (Silva et al., 2022) in solar tower (Maia et al., 2017) hybrid dryer in solar collector with dry intermittent (photothermal energy), and oven drying with cabinet drier different chambers (Camelo et al., 2019) and oven drying with forced air circulation (Kamal et al., 2023) and (Sá et al., 2021).

The main purpose of dehydration is to eliminate most water by evaporation with heat application. The reduction of water content by drying and osmotic dehydration (OD) results in lower water Activity in food. Low water activity values hinder the action of microorganisms and reduce enzymatic activity (Fellows, 2014). Moreover, kiln dries and OD combined results in many benefits of dried banana as better sensory and nutritional characteristics due to the concentration of constituents (Sousa et al., 2003; Sousa et al., 2003). Although the dried banana offered in the market has a pleasant taste, it presents dark color (Dourado et al., 2012). Several bleaching methods have been studied in other plants, such as: Steam Blanching in white Yam (Alenyorege et al., 2024), pretreatments with immersion in liquid nitrogen, steam blanching and freeze cycles in sea-buckthorn (Araya-Farias et al., 2014), blanching of avocados by immersion, with peel (Salvador-Reyes & Paucar-Menacho , 2019). Studies on bananas have been conducted in function of the OD of bananas followed by drying (Maeda, M. & Loreto, 1998; Rodrigues et al., 2013; Batista et al., 2014; Faria et al., 2020), of the syrup concentration (Sousa et al., 2003; Sousa et al., 2003), drying and rehydration by microwave after OD of slices of pineapple (Akhtaruzzaman et al., 2022), drying kinetics (Cano-Chauca et al., 2004; Borges et al., 2011), drying bananas in oven dryer (Boudhrioua et al., 2002; Couto et al., 2019; Farias et al., 2020), and the banana-juice obtained from fruits of different banana genotypes (Jesus et al., 2005; Mota, 2005; Viana, et al., 2017), bleaching and solution with citric acid pre-dehydration and immersion-impregnation (Borges, S. V. et al., 2011; Couto, L. A. et al., 2019), OD and sulphitation (Celestino, 2009), colorimetric analysis (Carvalho et al., 2011; Batista et al., 2014; Sousa et al., 2003). No studies have been conducted to evaluate drying, OD and prevention of enzymatic browning in dried banana, simultaneously.

A way to conserve the overproduction, avoid post-harvest losses and still add value is the processing in dried banana. The combined use of pretreatments to prevention the enzymatic browning is the alternative to improve the appearance of dried banana, as the pretreatments: Antioxidant (Jesus et al., 2005), Bleaching (Souza Filho et al., 1999) and Sulphitation (Stringheta et al., 2003). This study aims to evaluate pre-treatments of prevention and enzymatic browning and the use of osmotic dehydration and the influence on drying time, physicochemical characterization, proximate analysis, quality, color and yield.

2. MATERIALS AND METHODS

2.1 Harvesting of Banana Bunches

The raw material was obtained from banana trees of the Banana Research Program, of the experimental farm of Brazilian Agricultural Research Corporation - Embrapa Western Amazon, located on highway AM 10, km 29, Manaus, Amazonas. The cultivar Thap Maeo is productive, resistant to pests and diseases, with quality fruits, in addition to having good physicochemical characteristics (Jesus, S. C. et al., 2004), and for these characteristics was chosen among the cultivars recommended by Embrapa for the State of Amazonas. Bunches of bananas were harvested based on the visual criteria of the fruit such as: with onset of yellowing of firsthand and disappearance angular of the fruit according to the methodology described in (Pereira and Pereira 2005). A representative sample of four bunches was collected in 90 days, with fruits at stage three. For weighing of bunches was used graduated scale (Filizola™ model Pluris 15/6), with capacity for 50 kg, and for hands, scale with capacity for 15 kg. These were packed in boxes and immediately transported to the laboratory of biochemistry and post-harvest fruit physiology of the National Institute of Amazonian Research - INPA, Manaus/AM, Brazil.

2.2 Maturation of Fruits

The hands of bananas were removed manually from the bunches. Then, the hands were placed in polyethylene boxes, at room temperature (± 32 ºC), for ripening and relative moisture of air (± 86%), measured daily by thermo-hygrometer (HigroClock™). The fruits in stage three, reached Stage Six maturation after 12 days. This stage of maturation is indicated by the color of the peel completely yellow, according to the classification of Pereira & Pereira (2005), and PBMH e PIF (2006). Fruits of bananas were removed from the hands, and discarded the twinned fruits, with floral remains, with mechanical damage, paste and with rot.

2.3 Biometric Characterization

The biometric characterization was based on the methodology of (Jesus, 2004) e modified of (Silva et al., 2023). Sixty (60) hands with immature fruits (stage three) were used. Parameters evaluated: Bunch Weight (kg), Number of Hands per Bunch, Hand Weight (kg), Number of Fruits per Bunch, Number of Fruits per Hands, Number of Fruits 2nd Hand, Fruit Weight 2nd Hand (Kg). The following measurements were made of the average fruit of the 2nd palm: Fruit Weight (g), Pulp Weight (g), Peel Weight (g), Pulp/Peel ratio, Fruit Length (cm), Fruit Length Without Peel (cm), Fruit Diameter (mm), Fruit Diameter Without Peel (mm), Pulp (%), Peel (%) and Pulp yield (%). We used a representative sample of 30 fruits from different bunches. For fruit weighing was used on a semi-analytical scale (Mars™, model AS2000G). Measurements were performed with the aid of caliper Hélios Stainless, results expressed in centimeters (PBMH and PIF, 2006; Silva Filho and Moreira, 2005).

2.4 Processing of the Dried Banana from cv. Thap Maeo

For the processing of dried bananas 20 kg of fruits were used (Fig. 1). The fruits were selected without defects, with regular shapes, medium sizes and without irregularities in color. And subsequently, wash content ed in drinking water, sanitizing in 0.01% sodium hypochlorite solution (NaClO) for 15 minutes, rinse and peeling.

2.4.1 Prevention the enzymatic browning

Separation was performed in four lots for the pretreatments to prevention the enzymatic browning: for pretreatments with antioxidant solution, the fruits were quickly placed in solution with 0.25% ascorbic acid and 0.30% citric acid for five minutes, in proportion of 1:1.5, being 1 L of solution for 1.5 kg of peeled banana, according to the methodology of Jesus et al. (2005). In the bleaching, the fruits were peeled and quickly immersed in boiling water (96 ºC), for two minutes and immediate cooling, with immersion with water bath with ice for two minutes and drainage on sieves, according to the methodology of Souza Filho et al. (1999). In sulphitation, the fruits were placed in baskets and immersed in a container containing sodium metabisulfite ($Na_2S_2O_5$), concentration of 0.01% for 40 seconds, using 1 L of solution for 1.5 kg of peeled banana, according to the methodology of Cruz (1990).

2.4.2 Osmotic dehydration

After the pretreatments to prevention the enzymatic browning, the four lots (Control, antioxidant, bleaching and sulphitation), two lots each, being the first batch without osmotic dehydration. The second batch submitted to osmotic dehydration by immersion of the Fruit in sucrose solution at the concentration of 65°Brix for 6 h, in proportion fruit: sucrose solution (1:2), according to Sousa at al. (2003). The treatments were coded as: Control (C), Control with osmotic dehydration (COD), Antioxidant (A) and Antioxidant with osmotic dehydration (AOD), Bleaching (B), Bleaching with osmotic dehydration (BOD), Sulphitation (S), Sulphitation with osmotic dehydration (SOD).

2.4.3 Drying curve of dried banana

To obtain the drying curve of dried banana, the fruits were placed in aluminum pans, separated by treatments and three repetitions, in drying oven (Nova ética^{TM} model 420 / 6 D), and dried with forced air circulation, and maintained temperature of 65 ºC to constant weight. The samples of each treatment were weighed at the beginning of drying (every hour) until 2 h of drying, after this period were heavy every 2 h, to constant weight. It was made the revolving of the fruit for uniformization of the removal of water. The weighing was done on a semi-analytical scale (Marte^{TM}), with capacity of 5 kg, and the results were expressed in grams. Dried banana weight of each treatment was calculated by the difference of the initial weight and final weight. Bananas were placed in medium density plastic bags and stored in temperature of 25 ºC and in a dry and airy place. From 8 treatments: 4 pretreatments for the prevention enzymatic browning (C, A, B and S), and 2 methods of osmotic dehydration (COD, ADO, BOD and SOD) were used.

2.5 Proximate Analysis

Proximate analysis of *in natura* banana and dried banana cv. Thap Maeo, analyses were performed in triplicate: The parameters moisture, dry matter, protein content, crude fat and ash content were quantified according to Instituto Adolfo Lutz (2008).

2.5.1 Moisture content

Moisture (%) and dry matter (%) were determined for drying of the material in drying oven (Nova ética^{TM}, model ETC45), with forced air circulation and temperature of 65 ºC, dry to constant weight.

2.5.2 Protein content determination and crude fat content

The protein content (%) was quantified by the Micro-Kjeldhal method of total Nitrogen, with factor 6.25 for conversion of nitrogen into protein content. The crude fat (%) were extracted from the dry sample by the Soxhlet (Marconi^{TM}), using hexane as a solvent.

2.5.3 Ash content and crude fiber content

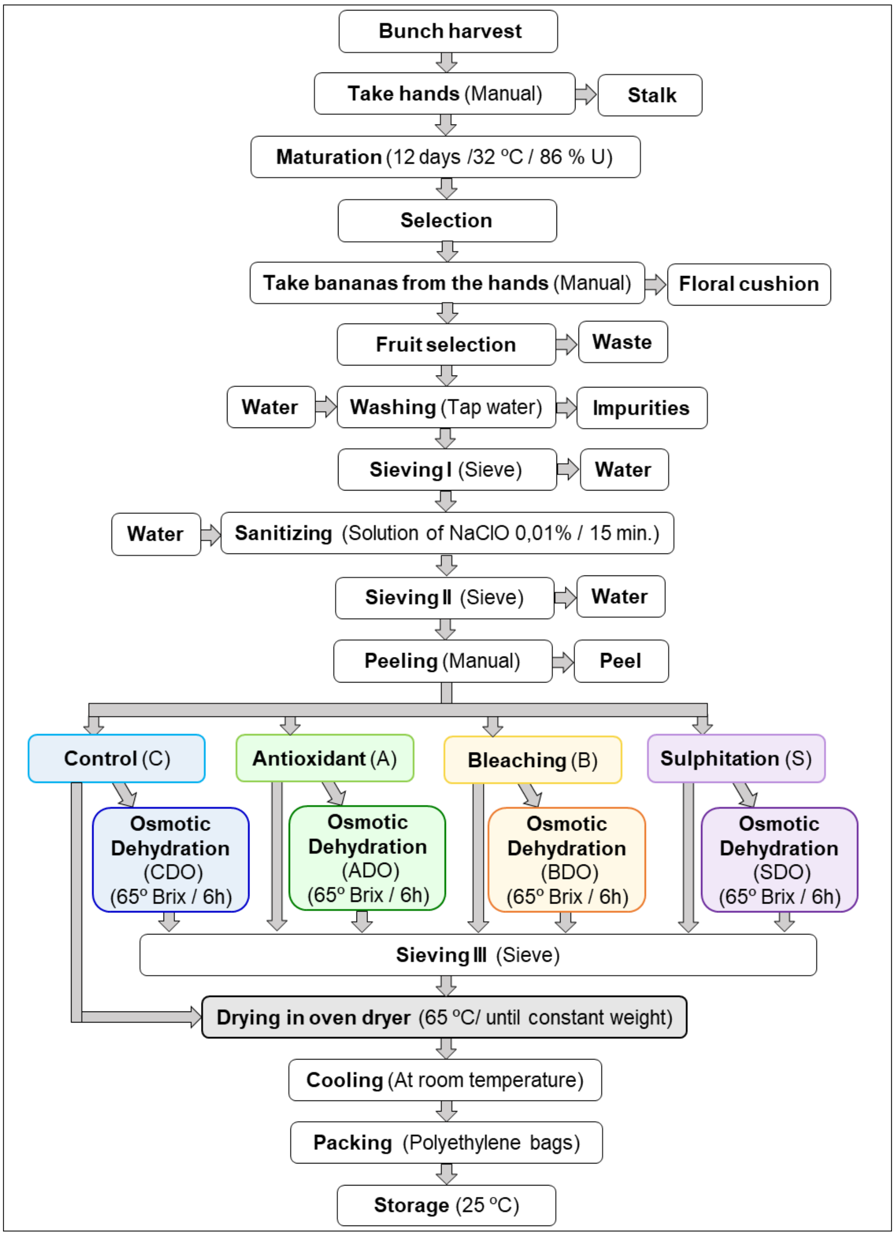
The ash content (%) was obtained by the incineration of the dry and defatted sample in muffle furnace (EDG^{TM}, model IP stainless steel), to 550 ºC for five hours. The total fibers were determined from the dry and defatted sample by acid digestion (H_2SO_4 a 0.255 N) and alkaline (NaOH a 0.313 N) in fiber determinator, of the brand Tecnal^{TM}, model TE-149, and results were expressed in (%).

2.5.4 Carbohydrates

The carbohydrates (%) were calculated by difference.

2.5.5 Sugars determination

The sugars were extracted at room temperature and quantified by the Somogyi-Nelson method (Southgate, 1991), the reducing sugars (%) and total sugars (%) in acid hydrolysis, under heating, and the non-reducing sugars (%) were calculated by difference.



C=Control, COD=Control with Osmotic Dehydration, A=Antioxidant, AOD=Antioxidant with Osmotic Dehydration, B=Bleaching, BOD=Bleaching with Osmotic Dehydration, S=Sulphitation, SOD=Sulphitation with Osmotic Dehydration.

Fig. 1. Flowchart to obtain dried banana cv. Thap Maeo. Methods for preventing enzymatic browning and dehydration. National Institute for Amazonian Research – INPA, Manaus/AM, Brazil

2.5.6 Phenolic compounds

The phenolic compounds were extracted in water, methanol 100%, and methanol 50% (Goldstein and Swain, 1963) and quantified by Folin-Denis reagent (Cliffe et al., 1994). Tannic acid (20 a 100 μg mL^{-1}). was used to obtain the standard curve. The equation of the straight line was used in the calculations whose results were expressed in (%).

2.5.7 Caloric value

The caloric value was estimated considering factors four (protein content and carbohydrates) and nine (crude fat). The Caloric value respective contents of these nutrients and the results were expressed in Kcal.

2.6 Physicochemical Characterization

The physicochemical characterization and chemical analysis of the pulps of the Fruit *in natura* and treatments were performed in samples of different bunches. The pulps were crushed in a food processor.

2.6.1 pH and Total Titrable Acidity (TTA)

The pH was determined according to Ranganna (1986), in pH meter (Micronal™, model B 474), previously calibrated with buffer solution, using sample without filtering, obtained from the homogenization of 5 g of pulp and 20 mL of distilled water. Total Titrable Acidity (TTA) was determined according to Ranganna (1986), performed by titration of the crushed sample and homogenized with 30 mL of distilled water with 0.1 N NaOH solution (standardized) and phenolphthalein as indicator. The results were expressed as percentage of malic acid.

2.6.2 Total Soluble Solids (TSS) and Sugar/acidity ratio (TSS/TTA)

Total Soluble Solids (TSS) was determined in refractometer (Belligran Stanley™) using the liquid phase of the pressing of the sample previously crushed in two layers of gauze, in a filter system under pressure in a syringe. Measurements that were that were not standard temperature (20 ºC) were corrected according to the conversion table of Ranganna (1986), and the results in ºBrix. Sugar/acidity ratio (TSS/TTA) was determined for ratio between Total Soluble Solids (TSS) and Total Titrable Acidity (TTA).

2.6.3 Texture

The texture of dried banana was determined in texturometer (Texture analyser, of Stable Micro Systems™, model TA-XT2), using the following test method operating conditions: measure of force and compression, distance of 5 mm, pre-test speeds of 2.0 mm/s, of test 2.0 mm/s and after test 5 mm/s with probe SMS P/N, and the results were expressed in Newton (N) (Boudhrioua et al., 2002). Twelve samples of each treatment were used, in slices of the bananas, with 1cm wide, cut in the central portion of the fruit. Measurements were performed immediately after sample preparation. Each sample was placed on the texturometer in the position that the outer surface was facing the probe.

2.6.4 Water activity (Aw)

The water activity (Aw) of banana dried was determined in AquaLab (Decagon™), by the technique of determining the dew point in encapsulated mirror (Braseq, 2023). The calibration of the equipment, before the readings, was done with standard pure water. The samples were cut into slices of 1 centimeter thickness, to occupy half the height of the reading container. The readings were performed immediately after removal from the package.

2.7 Dry Banana Yield

Dry Banana Yield (DBY%) was calculated by the ratio between 1000g of bananas with peel and the amount of dried banana, of each treatment.

2.8 Colorimetric Analysis

The external color and internal of dried banana was determined by the luminosity parameters (L*) and chromaticity (a* and b*), in colorimeter Spectrophotometer Portable (Sheen Instruments ™, model Micromatch Plus), light source D65 (6500°K), the observation angle of 10 and 30 mm measuring cell aperture, scale L*, a* and b* of the CIELab System, (Hunter, 1987), calibration before readings with white and black standard. L* value indicates brightness (L*=0 (black) and L*=100 (white)), a* and b* chromaticity, the data in the coordinates indicate the direction of color, where a* indicates the axis of chromaticity from green (-a) to red (+a) and b* the chromaticity axis from blue (-) to yellow (+). Luminosity and chromaticities of the endocarp were measured in the external parts of whole fruits and inner part of slices. Measurements were performed in triplicate at different points of the same sample and the results expressed in intensity of Luminosity (L*) and chromaticities (a*) and (b*). The experimental design was in a factorial scheme with four pretreatments for the prevention the enzymatic browning and two types of dehydration (with and without Osmotic Dehydration) and three replications.

2.9 Statistical Analysis

The data were tabulated in Microsoft Excel and submitted to Analysis of Variance (ANOVA). For the comparison of the means, the analysis of variance with F test and the Tukey test at ($P < 0,05$) probability. The program used was R Core Team (2024).

3. RESULTS AND DISCUSSION

3.1 Biometric Characterization of the Banana of cv. Thap Maeo

In the biometric characterization of the banana of cv. Thap Maeo, the characteristics of weight, number, bunches, hands and fruits, length and diameter of fruits with and without peel were evaluated (Table 1).

3.1.1 Number of hands per bunch and fruit per hands

Number of Hands per Bunch (Table 1) was superior to those found for Martins et al. (2022). There is a proportionality between Bunch Weight and Number of Hands. The number of fruits per bunch was larger than the one found for cv. Thap Maeo by Nogueira et al. (2018). The Number of Fruits per Hands was higher than found for cv. Thap Maeo by Silva Filho & Moreira (2005) a value close of Assis et al. (2022). The Number of Fruits 2nd Hand was higher than that found for cv. Thap Maeo in Santos and Carneiro (2012). According to Weber et al. (2017), the cv. Thap Maeo presented greater potential for production of bruches e fruits between twenty genotypes.

3.1.2 Bunch Weight

In the biometric characterization of the banana of cv. Thap Maeo, it was possible to observe that the values of Bunch Weight were high, considering large bunches (Table 1). These values were higher than those found for cv. Thap Maeo of Assis et al. (2022), Martins et al. (2022), Nogueira et al. (2018).

Table 1. Biometric characterization of bananas from cv. Thap Maeo. National Institute for Amazonian Research – INPA, Manaus/AM, Brazil

Characteristics	Mean	Standard deviation	Minimum	Maximum	Amplitude
Bunch Weight (kg)	28.38	± 3.4	25.00	31.50	6.50
Number of Hands per Bunch	15.00	± 0.8	14.00	16.00	2.00
Hand Weight (kg)	1.92	± 0.8	0.85	5.90	5.05
Number of Fruits per Bunch	269.00	± 22	247.00	288.00	41.00
Number of Fruits per Hands	19.58	± 7.5	10.00	59.00	49.00
Number of Fruits 2nd Hand	28.75	± 7.5	24.00	40.00	16.00
Fruit Weight 2nd Hand (Kg)	2.84	± 0.7	2.40	3.91	1.51
Fruit Weight (g)	102.72	± 9.5	81.48	124.12	42.64
Pulp Weight (g)	82.60	± 7.3	67.03	99.32	32.29
Peel Weight (g)	20.12	± 3.3	14.45	30.67	16.22
Pulp/Peel ratio	4.17	± 0.5	2.99	4.95	1.96
Fruit Length (cm)	12.00	± 0.5	10.72	12.93	2.21
Fruit Length Without Peel (cm)	10.64	± 0.5	9.38	12.08	2.70
Fruit Diameter (mm)	36.50	± 0.3	27.40	39.60	12.20
Fruit Diameter Without Peel (mm)	32.80	± 0.2	29.60	35.60	6.00
Pulp (%)	72.17	± 6.3	58.56	86.77	28.21
Peel (%)	27.83	± 6.3	13.23	41.44	28.21
Pulp yield (%)	80.47	± 2.1	74.93	83.20	8.27

3.1.3 Hands Weight and Fruit Weight 2nd Hand

Great variation in amplitude was observed between the maximum and minimum values of Hand Weight of 5.05 kg. The Hand Weight was higher than found for cv. Thap Maeo of Assis et al. (2022), and lower to Silva Filho and Moreira (2005). Hand Weight varied according to the location of the bunch, the first bunch being heavy, and the weight was decreasing proportionally along the cluster to reach the floral cushion. The 2nd hand is the heaviest and with the most fruit. The weight of fruits of the 2nd bunch was higher than that found for cv. Thap Maeo of Santos and Carneiro (2012).

3.1.4 Fruits weight

The values of Fruits Weight and Pulp Weight values show relatively heavy fruit. This may be due to fertilization and cultural practices that are used by Embrapa. Fruit Weight and Pulp was superior to that found for cv. Thap Maeo of Silva Filho and Moreira (2005).

3.1.5 Yield of fruit

A variation of 19.59% was found in relation to Fruit Weight, with this percentage to Peel Weight, 20.12 g. Pulp/Peel ratio was lower than Silva Filho & Moreira (2005). The percentage of Pulp (P%) was greater than 70% and the percentage of Peel (C%), less than 30% (Table 1). The pulp yield was considered high, higher than 80%. The value was close to the found for the cv. Thap Maeo of Jesus et al. (Jesus et al., 2004) and more than Nogueira et al. (2018).

3.1.6 Diameter and length

The values of the Fruit dimension refer to the average fruits, which were classified according to Fruit Length Without Peel as belonging to classes 12, by the fruit length being greater than 12 centimeters and less than 15 centimeters (PBMH and PIF, 2006). The Fruit Length Without Peel had approximate value cv. Thap Maeo of Ribeiro et al. (2012), from Saraiva et al. (2018). Fruit Length Without Peel if approximate value of Jesus et al. (2004). When evaluating the diameter of the fruits with peel and diameter of the fruits without peel (Table 1) it was observed that the fruits with peel included in the extra gauge category (34 mm), according to classification of PBMH & PIF (2006).

3.2 Proximate Analysis and physical and physicochemical characteristics

In the proximate analysis and physical and physicochemical characteristics of banana *in natura* of cv. Thap Maeo (Table 2).

Table 2. Proximate Analysis of the *in natura* banana cv. Thap Maeo. National Institute for Amazonian Research – INPA, Manaus/AM, Brazil

Parameters	Banana *(in natura)*	
	Mean	Standard deviation
Moisture content (%)	79.16	± 1.20
Dry matter (%)	20.84	± 1.20
Carbohydrates (%)	19.08	±1.10
Protein content (%)	4.06	± 0.04
Crude fat (%)	0.10	0
Crude fiber content (%)	1.50	0
Ash content (%)	0.10	0
Caloric Value (Kcal)	92.65	0
pH	4.68	± 0.01
Total Soluble Solid, TSS (ºbrix)	22.00	0
Total Titrable Acidity, TTA (% malic acid)	0.77	0
Sugar/acidity ratio (TSS/TTA)	28.47	0
Total Sugars (%)	8.75	± 0.40
Reducing Sugar (%)	7.15	± 0.60
Non-reducing Sugar (%)	1.62	± 0.20
Phenolic in water (%)	0.06	0
Phenolic in methanol 50% (%)	0.004	0
Phenolic in methanol 100% (%)	0	0

The moisture value was greater than 70% and the values found by Reis et al. (2016) and Godoy et al. (2016). The pH value was close to Reis et al. (2016), Godoy et al. (2016) and Carvalho et al. (2011). Total Titrable Acidity, TTA (% malic acid) of banana *in natura* was more than Reis et al. (2003) and Viana et al. (2017). The value of Total Soluble Solids (TSS) was close to that found Carvalho et al. (2011) and Viana et al. (2017). The Brix/Acidity ratio shows moderately sweet fruits with low acidity. The values of total sugars (%) and reducing sugars (%) were lower than the results found by Carvalho et al. (2011). The non-reducing sugars (%) were close to Reis et al. (2016). The phenolics contained in the banana *in natura* were extracted in greater quantity in aqueous solution. Protein content (%) and crude fat (%) was near lower than those found by Bezerra & Dias (2009). The carbohydrate content was higher than that found by Carvalho et al. (2011). The banana of cv. Thap Maeo is a source of fiber. And according to Gonçalves et al. (2010), the fibers attribute functional properties to food. The caloric value of fresh banana cv. Thap Maeo was 92.65 kcal.

3.3 Similarity with Other Varieties of the Apple Group and Silver Group

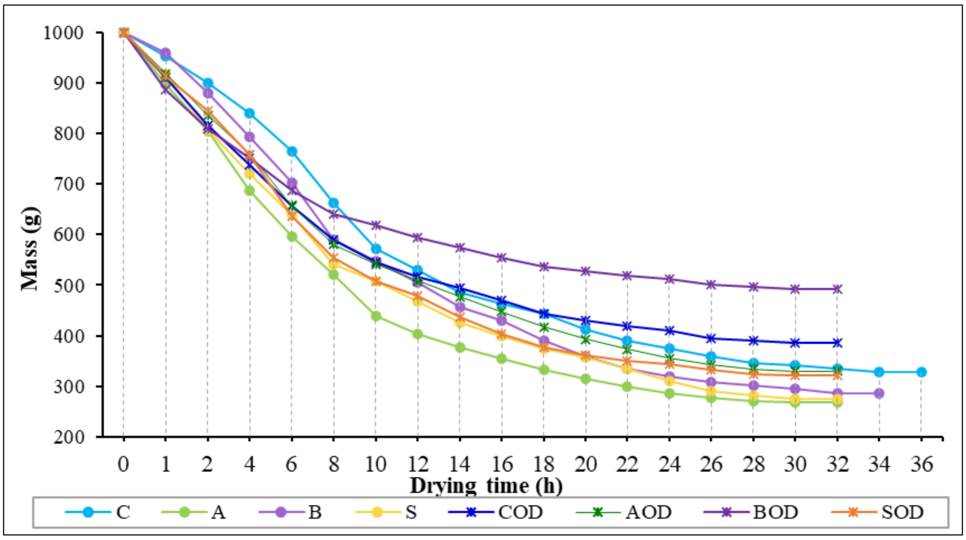
Regarding biometric characterization, proximate analysis and physicochemical characteristics, the bananas cv. Thap Maeo are very similar to the fruits of cv. Country and cv. FHIA 18 of the silver group. The similarity with other varieties of the apple group has already been verified by Carvalho et al. (2011) when evaluating the post-harvest quality of three cultivars of the apple group.

3.4 Drying Curve

In drying curve (Fig. 2), in the first eight hours of drying dried banana occurred weight loss of 40.51% to 59.65%, relative to the initial weight. These results are according to Farias et al. (2020) who observed great moisture removal at the beginning of the drying oven process.

3.4.1 Drying time

Treatments with osmotic dehydration had faster moisture removal than treatments without osmotic dehydration, especially in the first 8 hours. Treatment with COD was dry 4 hours before o C, and treatments with AOC, BOC and SOD dried 2 hours before of treatments A, B and S (respectively). The BOD pretreatments were easier to lose water in the first 2 hours, while COD, BOD, SOD lost more water in the first 6 hours. Most treatments had stabilization of dried banana weights with 32 hours in drying oven, however two treatments C and B stabilized the weight after 36 and 34 hours of drying. The drying of dried banana took place at a decreasing rate, in accordance with Lima et al. (2014).



Control (C), Antioxidant (A), Bleaching (B), Sulphitation (S), Control with osmotic dehydration (COD), Antioxidant with osmotic dehydration (AOD), Bleaching with osmotic dehydration (BOD), Sulphitation with osmotic dehydration (SOD).

Fig. 2. Drying curve of dried bananas of cv. Thap Maeo. Methods for preventing enzymatic browning and osmotic dehydration. National Institute for Amazonian Research – INPA, Manaus/AM, Brazil

The times found for drying in over dryer of dried banana at 65°C is proportional to the found drying times used by Cano-Chauca et al. (2004) when using air temperature of 60°C e 70°C, with drying time of 30 h and 36 h, respectively, and with moisture content of 23 to 25%. Farias et al. (2020) observed that temperature has a great influence on dry banana drying. For kamal et al. (2023), the effect of temperature (45, 55 and 62 °C) was evaluated, and it was observed that the temperature of 62 °C was the most appropriate. The drying curves determined the drying time for each treatment used to produce bananas. These are also important for the moisture content within the recommended range Cano-Chauca et al. (2004). According to ANVISA (2005) the dry banana should have a moisture content between 20% and 25%.

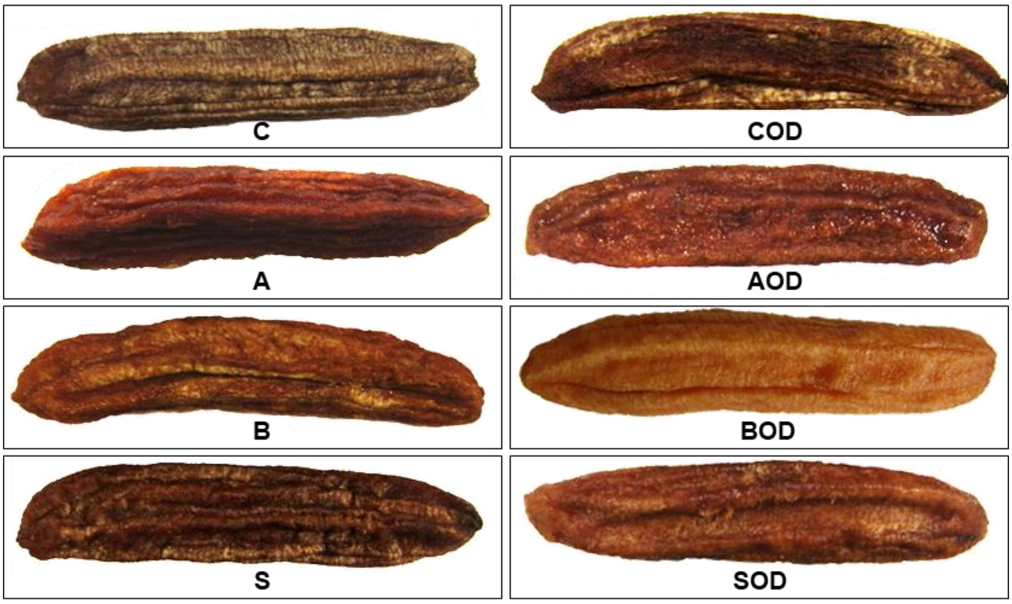
Treatments with osmotic dehydration were easier to lose water in the first hours due to the sucrose solution residue adhered to the surface of the fruits, which also contains water. The osmotic dehydration facilitates the loss of water in dried banana in drying oven because, in the process of drying, the air conducts heat to the food, causing evaporation of the water, being also the vehicle in the transport of the wet steam released from the food. Thus, a considerable part of the moisture is free on the surface of the banana and thus is easily removed (Cano-Chauca et al., 2004). The treatments that had more difficulty losing water mainly in the first eight hours were Control (C) and Bleaching (B). This result can be explained by the greater resistance in internal water loss. According to Cano-Chauca et al. (2004), the differences increase due to internal resistance to moisture transport, as during the drying water interacts with polar groups of constituent molecules.

3.5 Appearance of the Dried Banana of the cv. Thap Maeo

It is possible to observe the variation of appearance and color of dried banana as an effect of pretreatment and osmotic dehydration (Fig. 3).

3.6 Proximate Analysis of the Dried Banana of the cv. Thap Maeo

In the proximate analysis of the dried banana cv. Thap Maeo significant differences (Table 3), were observed between dehydration treatments for moisture, carbohydrates, ash content and caloric value (Table 4).



C=Control, COD=Control with Osmotic Dehydration, A=Antioxidant, AOD=Antioxidant with Osmotic Dehydration, B=Bleaching, BOD=Bleaching with Osmotic Dehydration, S=Sulphitation, SOD=Sulphitation with Osmotic Dehydration

Fig. 3. Aspects of dried banana cv. Thap Maeo. Methods for preventing enzymatic browning and osmotic dehydration. National Institute for Amazonian Research – INPA, Manaus/AM, Brazil

Table 3. Summary of analysis of variance of proximate analysis of dried banana cv. Thap Maeo. Methods for preventing enzymatic browning and osmotic dehydration. National Institute for Amazonian Research – INPA, Manaus/AM, Brazil

VS	MS					
	Moisture content	Carbohydrates	Protein content	Crude fat	Ash content	Caloric value
	(%)					(Kcal)
D.	52.3***	53.104***	0.01402^{ns}	0.000004^{ns}	0.0014***	821.2***
PEB	1.66***	0.6621***	0.1523***	0.00726***	0.00006*	24.08***
D.x PEB	0.28^{ns}	0.3260***	0.00038^{ns}	0.000026^{ns}	0.00003*	5.38***
Error	0.10	0	0.004300	0.000033	0.00001	0.08
CV%	7.55	2.15	4.44	10.28	2.22	2.05
GM	21.36	72.48	3.46	0.29	0.39	306.38
Min.	19.35	70.48	3.16	0.24	0.38	297.36
Max.	23.57	74.29	3.67	0.32	0.40	314.42

*MS=mean squared, VS=variation source; CV%=coefficient of variation; GM=general mean; D.=dehydration; PEB=prevention the enzymatic browning. Significant at the * P<0,05 probability level by F-test, significant at the *** P<0,001 probability level by F-test. ns, no significant at the P<0,05 probability level by F-test.*

Table 4. Proximate analysis of dried banana cv. Thap Maeo. Methods for preventing enzymatic browning and osmotic dehydration. National Institute for Amazonian Research – INPA, Manaus/AM, Brazil

Parameters	(OD)	Preventing of enzymatic browning									
		(C)		(A)		(B)		(S)		Mean	
Moisture content (%)	Without	23.3	aA	22.0	aA	23.5	aA	22.5	aA	22.9	a
	With	20.1	aA	19.7	aA	20.3	aA	19.4	aA	19.9	b
	Mean	21.7	A	20.9	B	21.9	A	21.0	B		
Carbohydrates (%)	Without	70.5	dA	71.3	aB	70.6	cB	71.3	bB	71.0	b
	With	73.7	dA	74.0	cA	74.3	bA	73.9	aA	74	a
	Mean	72.1	C	72.8	A	72.3	B	72.8	A		
Protein content (%)	Without	3.50	aA	3.64	aA	3.25	aA	3.54	aA	3.48	a
	With	3.44	aA	3.57	aA	3.22	aA	3.50	aA	3.43	a
	Mean	3.47	B	3.43	AB	3.41	C	3.52	A		
Crude fat (%)	Without	0.31	aA	0.31	aA	0.24	aA	0.31	aA	0.29	a
	With	0.30	aA	0.31	aA	0.24	aA	0.32	aA	0.30	a
	Mean	0.31	A	0.31	A	0.24	B	0.32	A		
Crude fiber content (%)	Without	3.0	aA	3.0	aA	3.0	aA	3.0	aA	3.0	a
	With	3.0	aA	3.0	aA	3.0	aA	3.0	aA	3.0	a
	Mean	3.0	A	3.0	A	3.0	A	3.0	A		
Ash content (%)	Without	0.38	bB	0.39	bA	0.38	bB	0.39	bAB	0.39	b
	With	0.40	aB	0.40	aA	0.40	aB	0.40	aAB	0.40	a
	Mean	0.39	BC	0.40	A	0.38	C	0.40	AB		
Caloric value (Kcal)	Without	299	bC	304	bA	298	bD	302	bC	301	b
	With	312	aC	313	aB	311	aC	314	aA	312	a
	Mean	305	B	308	A	304	C	308	A		

OD=Osmotic Dehydration, C=Control, COD=Control with Osmotic Dehydration, B=Bleaching, BOD=Bleaching with Osmotic Dehydration, S=Sulphitation, SOD=Sulphitation with Osmotic Dehydration, A=Antioxidant, AOD=Antioxidant with Osmotic Dehydration. Means followed by equal capital letters in the column do not differ from each other at P<0,05 probability by the Tukey's test. Means followed by equal lowercase letters on the row do not differ from each other at P<0,05 probability by the Tukey's test.

3.6.1 Moisture content

The treatments with osmotic dehydration showed lower values of moisture than the dry treatments in oven dryer. The average moisture (%) differed between the treatments for prevention of enzymatic browning, with lower values in the antioxidant treatments (A and ADO) and Sulphitation (S and SOD). This is due to the loss of water from the fruits to the solution during pretreatments, due to the concentration of solutes of the antioxidant solution (0.25% ascorbic acid and 0.30% citric acid) and sulphitation (0.01% sodium metabisulfite). However, the moisture % of treatments B and BOD did not differ statistically from the treatments C and COD. Thus, bleaching does not negatively interfere in moisture of the dried banana as the water content absorbed by the fruits during pre-treatments is lost in drying in oven dryer and osmotic drying.

The average moisture of the dried banana ranged from 19.35% to 23.57%. These values are within the limit of 25%, established for dried or dehydrated fruits by Resolution-DRC of ANVISA Nº 272/2005 (Anvisa, 2005). The transfer of water in the fruit by osmosis to the solution is due to the difference in osmotic pressures of the sucrose solution and the fruit (Sousa et al., 2003). Shi et al. (1995) reported the variables that slow down the diffusion speed of water molecules to the osmotic solution, such as the air contained in the fruit tissues, the air adhered to the fruit surface, and the air between the fruits and the sugar solution that obstruct the water transfer path. Most of the fruit water content is in the solutions of sugars, salts, protein content and organic compounds maintained in the cell compartments (Andrade et al., 1980).

There are significant differences between dehydration treatments for moisture. The treatments with osmotic dehydration showed lower values of moisture than the dry treatments in oven dryer. The moisture varied as a function of osmotic dehydration, because there was a lower residual moisture at the end of the production process of dried banana with these treatments. Osmotic dehydration at 65º Brix / 6 h, with in drying oven 65 ºC / 32 to 34 h, removed from 71.56% to 75.51% of the initial water content of the fruits. These results are within the parameters of Maeda & Loreto (1998), which found that osmotic solutions with 70º Brix removed up to 84% of the initial water content of the fruits and osmotic solutions with 60°Brix removed up to 58% of moisture. The moisture values of dried banana for all treatments were close to those found by Jesus et al. (2005) for cv. FHIA 18, by Batista et al. (2014).

3.6.2 Protein content and crude fat content

There was a significant difference between the averages for the treatment of prevention of enzymatic browning for the protein content (%) and crude fat (%) (Table 4). Treatments SDO and AOD had the highest average crude protein content. The values were lower than those found by Bezerra and Dias (2009) for crude protein, in dried banana cv. Thap Maeo. While the treatments B and BOD, presented the lowest average of crude fat. This is due to the bleaching process that in one of the steps uses boiling water (96 ºC) for two minutes. Thus, bananas lost a part of the crude fat to the water of Bleaching. The results were higher than that of Bezerra and Dias (2009) of crude fat in dried banana cv. Thap Maeo.

3.6.3 Ash content

Ash contents were influenced by osmotic dehydration and the prevention of enzymatic browning and interaction. The bleaching (B) had the lowest average of ash, demonstrating that in this treatment, there is loss of minerals contained in the banana, even with rapid submersion in water in white water (2 minutes), this time was sufficient for the flow of solute to lead to the loss of minerals.

3.6.4 Carbohydrates

The carbohydrate contents were influenced by osmotic dehydration and the prevention of enzymatic browning and interaction. The SDO treatments had the highest mean carbohydrate followed by ACO and BCO. Osmotic dehydration treatments (COD, AOD, BOD and SDO) had higher averages in relation to dry treatments in a Drying in oven dryer. The osmotic dehydration incorporated sugar in the dried banana due to the osmotic solution. In addition, sugar gain (mass transfer) is related to the intrinsic characteristics of fresh fruits, and the incorporation of sugars was influenced by the prevention of enzymatic browning due to the immersion of bananas in hot water, in the bleaching, and in the antioxidant and sulphitation solutions. The surface water after sieving left the medium less concentrated and attracted the osmotic solution, more concentrated.

3.6.5 Crude fiber content

The fiber contents did not differ between treatments, but the bananas had higher fiber concentration in relation to banana *in natura*, with dehydration. And according to Gonçalves et al. (2010) fibers beyond influence in food texture, confer the quality of functional foods.

3.6.6 Caloric value

The dried banana without osmotic dehydration (B) had the lowest caloric value. However, the osmotic solution increases the caloric value of the treatments by the incorporation of sugars. Accordingly, Sousa et al. (2003) observed that osmotic dehydration increased caloric value by incorporating soluble solids. Osmotic dehydration influenced the caloric values of dried banana, with increase in the caloric value of treatments with osmotic dehydration in relation to treatments without osmotic dehydration. There was a significant difference in the prevention of enzymatic browning. The interaction of osmotic dehydration treatments and prevention of enzymatic browning was significant for the caloric value, and the treatments with bleaching (B and BOD) showed lower caloric values. This was due to the reduction of carbohydrates, protein content and crude fat content during bleaching.

3.7 Physicochemical Characterization of Dried Banana cv. Thap Maeo

In the physicochemical characterization of dried banana cv. Thap Maeo were evaluated the following parameters: Dry Matter (DM), pH, Total Titrable Acidity (TTA), Total Soluble Solid (TSS), Sugar/acidity ratio (TSS/TTA), Texture, Activity Water (A_w) and Dried Banana Yield (DBY) (Table 5, Table 6 and Table 7).

Table 5. Summary of analysis of variance of physicochemical characterization of dried banana cv. Thap Maeo. Methods for preventing enzymatic browning and osmotic dehydration. National Institute for Amazonian Research – INPA, Manaus/AM, Brazil

VS	MS			
	Dry Matter (%)	**Texture** (N)	**Activity water**	**Dried Banana Yield** (%)
D.	52.303537***	4.2757*	0.008066***	269.742***
PEB	0.1664726**	2.3715*	0.0051000***	63.424***
D.x PEB	0.281915^{ns}	0.0268^{ns}	0.0002778^{ns}	44.805***
Error	0.131646	0,7072	0.0001083	0
CV%	2.05	37.60	5.49	0
GM	78.64	2.65	0.61	24.25
Min.	76.43	1.16	0.57	19.38
Max.	80.65	4.80	0.67	35.58

*MS=mean squared, VS=variation source; CV=coefficient of variation; GM=general mean; D.=dehydration; PEB=prevention the enzymatic browning. Significant at the * P<0,05 probability level by F-test, significant at the *** P<0,001 probability level by F-test. ns, no significant at the P<0,05 probability level by F-test.*

Table 6. Summary of analysis of variance of physicochemical characterization of dried banana cv. Thap Maeo. Methods for preventing enzymatic browning and osmotic dehydration. National Institute for Amazonian Research – INPA, Manaus/AM, Brazil

VS	MS			
	pH	**TTA** (% malic acid)	**TSS** (ºBrix)	**TTA/TSS**
D.	0.113438***	1.20154***	591.034***	3325.495837***
PEB	0.097071***	0.07044***	0.006***	104.3721138***
D.x PEB	0.004837***	0.00184***	0.006***	26.315437***
Error	0.000196	0	0	0.000100
CV%	3.06	18.72	8.45	26.77
GM	4.43	1.33	60.00	47.49
Min.	4.17	0.98	55.00	32.65
Max.	4.67	1.69	65.00	66.11

*MS=mean squared, VS=variation source; CV=coefficient of variation; GM=general mean; D.=dehydration; PEB=prevention the enzymatic browning, TTA=Total Titrable Acidity, TSS=Total Soluble Solid, TTA/TSS= Sugar/Acidity Ratio. Significant at the *** P<0,001 probability level by F-test*

Table 7. Physicochemical characterization of dried banana cv. Methods for preventing enzymatic browning and osmotic dehydration. National Institute for Amazonian Research – INPA, Manaus/AM, Brazil

Parameters	(OD)	Preventing of enzymatic browning									
		(C)		(A)		(B)		(S)		Mean	
Dry Matter DM (%)	Without	76.7	aA	78.0	aA	76.5	aA	77.5	aA	77.1	B
	With	79.9	aA	80.3	aA	79.7	aA	80.6	aA	80.1	A
	Mean	78.3	B	79.0	A	78.1	B	79.1	A		
pH	Without	4.47	bA	4.38	bC	4.18	bD	4.42	bB	4.36	B
	With	4.65	aA	4.55	aB	4.33	aD	4.48	aC	4.50	A
	Mean	4.56	A	4.47	B	4.26	C	4.45	B		
Total Titrable Acidity TTA (% malic acid)	Without	1.55	aB	1.69	aA	1.48	aC	1.48	aC	1.55	A
	With	1.12	bB	1.26	bC	1.05	bC	0.98	bD	1.09	B
	Mean	1.34	B	1.48	A	1.27	C	1.20	D		
Total Soluble Solid TSS (ºBrix)	Without	55.0	bB	55.1	bA	55.0	bB	55.1	bA	55.0	B
	With	65.0	aA	64.9	aC	64.9	aC	64.9	aB	65.0	A
	Mean	60.0	A	59.8	C	59.8	C	59.9	B		
Sugar/acidity ratio (TSS/TTA)	Without	35.6	bC	32.7	bD	37.3	bB	37.3	bA	35.7	B
	With	57.8	aC	51.4	aD	61.7	aB	66.1	aA	59.3	A
	Mean	46.7	C	42.0	D	49.5	B	51.7	A		
Texture T (N)	Without	2.38	aA	3.86	aA	2.75	aA	3.29	aA	3.07	A
	With	1.45	bA	2.93	bA	2.10	bA	2.41	bA	2.23	B
	Mean	1.91	B	3.40	A	2.43	AB	2.85	AB		
Activity Water (A_w)	Without	0.64	aA	0.60	aA	0.67	aA	0.61	aA	0.63	A
	With	0.58	aA	0.57	aA	0.64	aA	0.58	aA	0.59	B
	Mean	0.61	B	0.59	C	0.66	A	0.60	BC		
Dried Banana Yield DBY (%)	Without	23.7	bA	19.4	bD	20.7	bB	19.8	bC	29.0	B
	With	27.8	aB	23.8	aC	35.6	aA	23.3	aD	38.2	A
	Mean	35.6	B	29.9	C	39.0	A	29.9	D		

OD=Osmotic Dehydration, C=Control, COD=Control with Osmotic Dehydration, B=Bleaching, BOD=Bleaching with Osmotic Dehydration, S=Sulphitation, SOD=Sulphitation with Osmotic Dehydration, A=Antioxidant, AOD=Antioxidant with Osmotic Dehydration. Means followed by equal capital letters in the column do not differ from each other at P<0,05 probability by the Tukey's test. Means followed by equal lowercase letters on the row do not differ from each other at P<0,05 probability by the Tukey's test.

3.7.1 Dry matter

In the physicochemical characterization of dried banana cv. Thap Maeo there was a significant difference in dry matter content (%) in relation to the type of dehydration (Table 5). The sucrose solution influenced the DM (%) of treatments with osmotic dehydration because it was adhered to the surface of the processed fruits and the incorporation of sugar, leading to increased mass. There was a significant difference in dry matter content (%) in relation to the type of prevention of enzymatic browning. Among them, the antioxidant treatments (A and AOD) and Sulphitation (S and SDO) had the highest dry matter values, while the control (C and COD) and bleaching (B and BOD) had the lowest values (Table 7). These last values found were close to those of Reis et al. (2016) for dried banana cv. Country.

3.7.2 Texture

In relation to texture, there was a significant difference in relation to osmotic dehydration and prevention of enzymatic browning. Osmotic dehydration that favored products with lower texture, that is, softer. This was due to the interaction of osmotic solutions with the surface layers of the fruits. The values of Texture were lower than those found by Jesus et al. (2005) for dried banana from cv. FHIA 18 and by Reis et al. (2016) for cv. Country. The treatments COD, BOD and SDO treatments favored softer products.

3.7.3 Activity water

There was a significant difference in Activity Water (Aw) in relation to dehydration and the type of prevention of enzymatic browning. The osmotic dehydration that favored products with lower Aw. The treatment BOD favored higher water activity. This is due to the soaking of the fruits in boiling water during bleaching, which facilitated the entry of water. However, the presence of sugar increases the osmotic pressure of the medium thus creating unfavorable conditions for the growth and reproduction of most microorganisms. Although the bleaching provided the highest values of water activity, all treatments were in the range allowed for dehydrated fruits from 0.50 to 0.85 according to Celestino (2010). The values of water Activity were lower than those found by Sousa et al. (2003), Batista et al. (2014) and Rodrigues (2013).

3.7.4 pH

The interaction of treatments was significant for pH. Osmotic dehydration gave slightly more alkaline products, and bleaching, slightly more acidic products. Perfeito et al. (2015) also observed slightly lower pH in mangabas processed with Bleaching. The objective of the Bleaching is the inactivation of browning enzymes. According to Celestino (2010), the optimum pH for inactivation of the polyphenoloxidase enzyme is at pH close to 4.0. This explains the successful inactivation of the browning enzyme during the Bleaching. The pH values were similar to those of Rodrigues (Rodrigues et al., 2013).

3.7.5 Total Titrable Acidity (TTA)

The interaction of treatments was significant for Total Titrable Acidity (%). The drying in oven dryer presented products with higher Titrable Acidity values, while the antioxidant treatment (A) showed the highest value. This is due to the immersion of bananas in solutions with organic acids. According to Celestino (2010) the use of antioxidants and Bleaching prolong the shelf life of dehydrated products. The values found were similar to those of (Jesus et al., 2005) in cv. FHIA 18, higher than those of Faria et al. (2020) in cv. Plantain and of Reis et al. (2016) in cv. Country, and approximate value of Batista et al. (2014).

3.7.6 Total Soluble Solids (TSS)

The interaction of treatments was significant for Total Soluble Solids (TSS). The osmotic dehydration favored the product with higher TSS values, having 10 ºBrix higher than drying in oven dryer, with the incorporation of around 18% of sugar in bananas of the initial weight of the fruits. higher value of incorporation of sucrose in relation to the initial weight was in COD. These values are higher than the one found by Maeda & Loreto (1998), about 10%.

The values found were close to Jesus et al. (2005) and Viana et al. (2017). And lower values than Mota (2005), Sousa et al. (2003), Rodrigues (2013), Batista et al. (2014). This sucrose incorporation was the same for all treatments until osmotic equilibrium, with the same TSS value of the osmotic solution, 65°Brix. Osmotic balance is a consequence of water loss from the fruit to the solution Shi et al. (1995). Sousa et al. (2003a) observed that sucrose does not diffuse easily through the cell membrane. And Maeda and Loreto (1998) observed that the equilibrium value with osmotic solution limits the final water content in the food.

3.7.7 TTA/TSS ratio

The interaction between treatments was significant for the sugar/acidity ratio (TSS/TTA). Osmotic dehydration favored higher value of TSS/TTA, for all treatments in relation to treatments drying in oven dryer. These values were influenced by the total soluble solids (TSS). According to Gonçalves et al. (2009) this relationship measures the degree of sweetness in the fruits. These values were higher than those of Jesus et al. (2005), Batista et al. (2014) and Faria et al. (2020). The SDO treatment had the highest value of TSS/TTA. However, the lowest value found was for pretreatments Antioxidant, because it has a higher concentration of organic acids (citric acid and ascorbic acid).

3.8 Dry Banana Yield

Dry Banana Yield DBY (%) considers the weight of bananas *in natura* and the final weight of bananas (Table 6). There was interaction between osmotic dehydration and prevention of enzymatic browning for the concentration of Dried Banana Yield DBY (%) (Table 5).

The BOD treatment presented the highest Dried Banana Yield DBY (%). This was due to the incorporation of sugar and sucrose solution adhered to the surface of the dried banana. An increase for DBY (%) was observed of 11.91% in the bleaching (BOD) compared to control (C). The immersion of bananas *in natura* in water during bleaching favored the greater retention of water, in this treatment, compared to the others. The yields of dry banana produced with osmotic dehydration were higher than those found by Jesus et al. (2005).

3.9 Colorimetric Analysis

Color External and internal were available (Table 8 and Table 9). It was possible to observe that there are significant differences in color of dried banana as an effect of pretreatment and effect of osmotic dehydration. However, the interaction is no significant at the P<0,05 probability level by F-test.

3.9.1 Color External

Osmotic dehydration and prevention of enzymatic browning significantly influenced the color (External) of dried banana, with colorimetric differences for luminosity L*, chromaticity a* and saturation b*. The luminosity L* defines the color to be lighter or darker, having as limits black and white. In all treatments the L* values were positive, indicating greater luminosity. With the bleaching, there was inactivation of the tanning enzyme during the process. This gave a higher L* value compared to the other samples and consequently lighter color, because the lower the L* value, the darker the color of the product. This gave a higher L* value compared to the other samples and consequently lighter color, because the lower the L* value, the darker the color of the product. The values for L*were close to Batista et al. (2014) and Sousa et al. (2003).

The chromaticity a* (hue) defines the color tone, having as limits the green and red. In banana it is expected colors ranging from red (chromaticity) to yellow (saturation), with brightness varying according to dehydration method used. In all treatments the values of a* were positive, indicating the color to red. However, treatments with osmotic dehydration have lower values of a*, with lower red saturation. The bleaching influenced the chromaticity a* values, indicating more saturated red. These values are close to those found by Batista et al. (2014), chromaticity a* from 9 to 11. The treated with organic acids (A and AOD), they presented reddest colour due to the formation of red pigmentation, indicated by the coordinates analyzed. This result is similar to the one found by Silva et al. (2023).

Saturation b* (chroma) defines the intensity or purity of chromaticity, having as limits the blue and yellow. In all treatments the b* values were positive, indicating the color to yellow more saturated. The bleaching influenced the values of saturation b*, indicating more saturated yellow. This coloration is due to the inactivation of enzyme of enzymatic browning.

3.9.2 Color internal

Osmotic dehydration significantly influenced the (internal) color of the dried banana. Treatments with osmotic dehydration presented the lowest values for luminosity L* and saturation b*. The treatments COD with slightly darker and red color compared to treatments without osmotic dehydration. This result is due to incorporation of the caramelized osmotic solution. However, among the methods of and prevention of enzymatic browning, only the bleaching (B and BOD) and addition of organic acids (A and AOD) where the treatments were effective with higher values for luminosity L*, chromaticity a* and

Table 8. Summary of analysis of variance of external color and internal color of dried banana cv. Thap Maeo. Methods for preventing enzymatic browning and osmotic dehydration. National Institute for Amazonian Research – INPA, Manaus/AM, Brazil

VS	MS					
	Color (External)			Color (Internal)		
	L*	a*	b*	L*	a*	b*
D.	14.664***	6.3654***	30.600***	43.255**	3.800^{ns}	63.148**
PEB	60.148***	18.9431***	40.502***	47.620***	12.129*	41.568**
D.x PEB	0.067 ^{ns}	0.1044^{ns}	0.070^{ns}	8.177^{ns}	04.720^{ns}	6.858^{ns}
Error	0.090	0.1214	0.144	3.485	2.431	5.870
CV%	11.76	22.76	40.64	9.55	19.14	22.50
GM	24.88	7.43	6.38	35.63	10.52	16.11
Min.	20.13	5.29	3.39	29.67	6.16	10.44
Max.	29.99	10.94	11.85	41.07	13.50	23.94

*MS=mean squared, VS=variation source; CV=coefficient of variation; GM=general mean; D.=dehydration; PEB=prevention the enzymatic browning. Significant at the * P<0,05 probability level by F-test, Significant at the ** P<0,01 probability level by F-test. Significant at the *** P<0,001 probability level by F-test. ns, no significant at the P<0,05 probability level by F-test*

Table 9. Color external and internal color of dried banana cv. Thap Maeo. Methods for preventing enzymatic browning and osmotic dehydration. National Institute for Amazonian Research – INPA, Manaus/AM, Brazil

Parameters		(OD)	Preventing of enzymatic browning									
			(C)		(A)		(B)		(S)		Mean	
Color (External)	L*	Without	22.2	aA	25.1	aA	30.0	aA	25.3	aA	25.7	a
		With	20.7	aA	23.8	aA	28.2	aA	23.6	aA	24.1	b
		Mean	21.4	C	24.5	B	29.1	A	24.5	B		
	a*	Without	6.4	aA	7.6	aA	10.7	aA	7.0	aA	7.9	a
		With	5.5	aA	6.8	aA	9.3	aA	6.1	aA	6.9	b
		Mean	6.0	D	7.2	B	10.0	A	6.6	C		
	b*	Without	4.3	aA	3.8	aA	9.2	aA	3.8	aA	5.3	b
		With	6.5	aA	6.3	aA	11.4	aA	5.8	aA	7.5	a
		Mean	5.4	B	5.1	B	10.3	A	4.8	B		
Color (Internal)	L*	Without	35.2	aA	39.1	aA	40.5	aA	33.1	aA	37.0	a
		With	31.0	aA	34.9	aA	37.4	aA	33.8	aA	34.3	b
		Mean	33.1	B	37.0	A	38.9	A	33.5	B		
	a*	Without	10.5	aA	11.1	aA	11.8	aA	10.3	aA	10.9	a
		With	7.07	aA	11.3	aA	12.3	aA	9.8	aA	10.1	a
		Mean	8.76	B	11.2	AB	12.1	A	10.1	AB		
	b*	Without	16.7	aA	17.8	aA	21.9	aA	14.5	aA	17.7	a
		With	11.6	aA	14.1	aA	17.9	aA	14.4	aA	14.5	b
		Mean	14.2	B	16.0	AB	19.9	A	14.4	B		

OD=Osmotic Dehydration, C=Control, COD=Control with Osmotic Dehydration, B=Bleaching, BOD=Bleaching with Osmotic Dehydration, S=Sulphitation, SOD=Sulphitation with Osmotic Dehydration, A=Antioxidant, AOD=Antioxidant with Osmotic Dehydration. Means followed by equal capital letters in the column do not differ from each other at P<0,05 probability by the Tukey's test. Means followed by equal lowercase letters on the row do not differ from each other at P<0,05 probability by the Tukey's test.

saturation b* on inside, with better coloring to being more lighter, yellow and red. The results of chromaticity b* were similar to those found by Batista et al. (2014). The coordinate a* represents the combination of green and red showing the brown color resulting from enzyme reactions (phenolases), showing the importance for the study of enzymatic browning Faria et al. (2020).

4. CONCLUSION

Osmotic dehydration gave the dried banana higher values of dry matter, carbohydrates, total soluble solid and brix/acidity ratio, ash content, caloric value, and lower water activity, moisture content, lower texture and lower total titrable acidity. Among the methods of pre-treatments antioxidant and sulphitation, bleaching was the best in prevention the enzymatic browning in dried banana, with lower values of crude fat, caloric value, dry matter, pH, total titrable acidity, texture (less hard), low moisture content, water activity within standards, high sugar/acidity ratio, highest and yield of dried banana, and higher values of L*, a* and b* on the outside and inside that attributed better coloring being more yellow, red and light. Bleaching technology is associated with osmotic dehydration to produce dried bananas from cv. Thap Maeo can be a viable strategy for adding value and conservation of bananas *in natura.* And it is an opportunity for the agribusiness in the production of bananas and will serve as a basis for Local Productive Arrangements - APL's, in Amazonas. We recommend that further studies on banana bleaching be carried out with peel, steam blanching, of immersion in liquid nitrogen, freeze cycles, and loss of minerals.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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