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Sugarcane pickles: from waste to processed food

Picles de cana-de-açúcar: do resíduo ao alimento processado

Encurtidos de caña de azúcar: de residuo a alimento procesado

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Abstract
The rational use of crop residues such as sugarcane tips to produce food that may serve man still requires a lot of research. Thus, we carry out a study that used the apical part of sugarcane stem (tip), very similar to the common palm heart, in the production of a new type of palm heart, coming from an abundant crop in Brazil that faces ecological problems due to the high generation of waste. This work aimed: (a) to adapt the common palm heart pickles production method to produce sugarcane pickles from the tips; (b) to determine the best maturation stage of sugarcane to obtain the highest nutritional quality of sugarcane pickles; and (c) to analyze the nutritional composition (moisture, ash, lipids, carbohydrates, proteins) of sugarcane pickles. Since there is no particular scientific methodology for this type of pickles a methodology adapted from traditional palm heart pickles processing was tested. Based on the results obtained, the adaptation of the traditional palm heart production method was satisfactory to produce sugarcane pickles. Furthermore, sugarcane pickles with shorter maturation are nutritionally superior when compared to those that were left for longer in the field.
Keywords: *Saccharum officinarum*; Food processing; Percent composition; New foods.

Resumo
O uso racional de restos culturais, como as ponteiras da cana-de-açúcar, visando a produção de alimentos que venham servir ao ser humano, ainda requer muitas pesquisas. Dessa maneira procurou-se efetivar um estudo que utilizasse a parte apical do colmo da cana-de-açúcar, que se assemelha em muito com o palmito comum de palmeira, na produção de um novo tipo de palmito, advindo de uma cultura abundante no estado e que enfrenta problemas ecológicos devido à alta geração de resíduos. Assim, os objetivos deste trabalho foram: a) adaptação do método de produção do palmito comum, para a produção do palmito da ponteira da cana; b) determinar o melhor estágio de maturação da cana para obter a maior qualidade das conservas e c) analisar a composição nutricional (umidade, cinzas, lipídeos, carboidratos, proteínas) do palmito da ponteira da cana para compararmos com o palmito comum e o broto de bambu. Devido ao fato de não existir uma metodologia científica particular para este tipo de palmito, foi testada uma metodologia adaptada do processamento do palmito tradicional. Diante dos resultados obtidos pode-se concluir que a adaptação do método de produção do palmito tradicional para o processamento do palmito da ponteira da cana é satisfatória; as conservas produzidas a partir de cana com menor tempo de maturação apresentam-se nutricionalmente superiores quando comparadas as que foram deixadas por mais tempo o campo.
Palavras-chave: *Saccharum officinarum*; Processamento de alimentos; Composição centesimal; Novos alimentos.

Resumen
El uso racional de los restos culturales, como las puntas de caña de azúcar, con el objetivo de producir alimentos que sirvan al ser humano, aún requiere mucha investigación. De esta manera, se intentó realizar un estudio que utilizó la parte apical del tallo de la caña de azúcar, que es muy similar al palmito común, en la producción de un nuevo tipo de palmito, proveniente de un cultivo abundante en la y que enfrenta problemas ecológicos por la alta generación de residuos. Así, los objetivos de este trabajo fueron: a) adaptación del método de producción de palmito común, para la producción de palmito a partir de la punta de la caña; b) determinar la mejor etapa de maduración de la caña de azúcar para obtener la mayor calidad de las conservas y c) analizar la composición nutricional (humedad, cenizas, lípidos, carbohidratos, proteínas) del palmito de punta de caña para comparar con el palmito común y el brote de bambú. Debido a que no existe una metodología científica específica para este tipo de palmito, se probó una metodología adaptada del procesamiento de palmitos tradicionales. En vista de los resultados obtenidos, se puede concluir que la adaptación del método tradicional de producción de palmitos al procesamiento de palmitos a punta de caña es satisfactoria; las conservas producidas a partir de caña de azúcar con un tiempo de maduración más corto son nutricionalmente superiores en comparación con las que se dejan en el campo por más tiempo.
Palabras clave: *Saccharum officinarum*; Procesamiento de alimentos; Composición centesimal; Nuevos alimentos.

1. Introduction

Currently, the international articulation to promote sustainable development and the eradication of poverty is grouped and is effective in an agenda of actions articulated by the countries-States of the United Nations (UN). Agenda 2030 is a plan of action for people, the planet, and prosperity. UN recognizes that eradicating poverty in all its forms and dimensions, including extreme poverty, is the greatest global challenge and an indispensable requirement for sustainable development. The 17 Sustainable Development Goals and 169 targets demonstrate the scale and ambition of this new universal Agenda. They seek to realize the human rights of all and to achieve gender equality and the empowerment of all women and girls. They are integrated and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental (UNSD, 2016).

The Goals and targets will stimulate action over the next fifteen years in areas of critical importance for humanity and the planet. Our work is in line with objectives 2 and 12 (Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture and, Goal 12: Ensure sustainable consumption and production patterns).

Brazil is the largest producer of sugarcane in the world and São Paulo state is considered the Brazilian largest sugarcane producer which was responsible (2020/2021 crop) for over 50% of sugarcane production (350 million tons) and ethanol production (13 million m3) (UNICA, 2022).

In sugarcane harvesting, the sugarcane stems (tip) are removed because this region depreciates its quality leaving the juice with low sucrose content and high concentrations of reducing sugars, water, phenolic compounds, organic acids, amino acids, and polysaccharides, which are considered undesirable on sucrose crystallization and juice clarification processes (Stupiello, 2000; Ravaneli et al., 2008; Novaes et al., 2011). Thus, the technical recommendation is to process the sugarcane stalks by withdrawing from two to three internodes below the breaking point of the sugarcane tip (pickles). Tips are considered sugarcane production residue and are commonly used in animal feed, or used as fodder material, can be also left in the field to be burned or incorporated into the soil (Azzini et al., 1992; Ramos & Gonçalves, 2018; Lourenço, 2018; Castioni et al., 2021).

Sugarcane is the crop that most generates waste in Brazil; refineries' implementation of environmental management systems requires management awareness, prioritization, and prediction of human resources and financial resources attributing environmental, social, and, economic responsibility (IPEA, 2016). The large waste volume generated in sugarcane industrialization makes it impracticable for refineries to store these residues and, for this reason, waste removal must occur efficiently and quickly so that its use as reusable by-products becomes possible (Jendiroba, 2006). Many scientific research efforts are to develop new technologies for agro-industrial waste use in human food, with a view to food security, increasing the rural producer's income, and reducing environmental impact (Vernaza et al., 2009; Coutinho et al., 2013; da Silva & Jorge;

2017).

The only scientific study of sugarcane pickles production as an option for food was made by Azzini and collaborators in Instituto Agronômico de Campinas (IAC) in the early 1990s. The authors verified the technical feasibility of sugarcane tips palm heart, which shows light color, soft texture, segmented structure, and crude protein contents very similar to those found in conventional palm heart (Euterpe edulis).

This work aimed to develop sugarcane pickles manufacturing protocols from the sugarcane tips, commonly left in the field after harvest. We produced sugarcane heart pickles with 3 maturation periods (9, 12, and 16 months) to evaluate better maturation stages.

2. Methodology

2.1 Samples

Sugarcane (Saccharum officinarum, variety RB 867515) was collected at UMOE Refinery located in Sandovalina-SP (22 ° 33'43.3" South and 51 ° 49'43.3" West WG and 389 meters altitude). Harvesting took place at different maturation stages (9, 12, and 16 months after planting) and, all materials, facilities, and equipment (knives, spoons, boards, pans, stainless steel table, and containers) used were sanitized following the recommendations of Raupp and Chaimsohn (2001). The raw material was the meristematic part of sugarcane "tip". NaCl (cooking salt), water, citric, and acetic acid were also used for processing.

2.2 Production of sugarcane heart pickles

After collecting, the sugarcane tips were transported in plastic boxes and then cut separating the meristematic part of the stem where the palm heart is (sugarcane heart). The samples previously separated by maturation were washed in running water and immediately immersed in solution (3% NaCl and 1% acetic acid). This immersion aimed to prevent and inhibit the oxidizing action, thus preventing the darkening of raw material.

Sequentially, sugarcane hearts were boiled for 15 minutes in acidified brine at 98 °C. The brine used was made with NaCl (2.5%), citric, and acetic acid (both 0.1%). After the procedure sugarcane hearts were placed in stainless steel sieves at room temperature to drain the brine and, avoid the final product overheating. We use sterilized glass containers 13.5 cm and 8 cm in diameter. Pickles were made in the proportion of 350 g of sugarcane heart to 230 g of brine and then the packages were sealed.

2.3 Performed Analyzes

Percent composition analyses were performed (moisture, proteins, lipids, ashes, and carbohydrates), as well as determinations of total acidity and pH, both raw material and pickles. All analyzes were based on procedures proposed by Health Ministry (IAL, 2008).

Percent composition

- Proteins (%): total protein contents were determined from total nitrogen contents, using factor 6.25 for calculation, following the 037/IV method (IAL, 2008);
- Total Lipids (%): total lipids were determined by the hot extraction method (Soxhlet), following the 032/IV method (IAL, 2008);
- Moisture (%): moisture content was determined using the oven drying method by sample weight loss when heated to 105 °C. The methodology was according to the 012/IV method (IAL, 2008);

- Ashes (%): total minerals were determined by muffle incineration at 550° C until the ashes were white or slightly grayish, following the 018/IV method (IAL, 2008);
- Carbohydrates (%): carbohydrate content was calculated by the difference between 100 and the other constituents' amounts (moisture, proteins, total lipids, and ashes) (TACO, 2011).
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pH

pH value was performed in a digital pHmeter according to the 017/IV method (IAL, 2008).

Total acidity

This method is determined by the citric acid content present in the sample, defining the acidity degree. The results were transformed into grams of citric acid.100 g-1 of the sample, according to the 312/IV method (IAL, 2008).

Energy Value

Products energy values were calculated using conversion factors and specific coefficients that take into account the heat of combustion and digestibility of each component. According to protein, lipid, and carbohydrate content: 4 kcal.g^{-1} protein, 4 kcal.g^{-1} carbohydrate and 9 kcal.g^{-1} fat (Brasil, 2003; Taco, 2011).

2.4 Experimental design and statistical analysis

We used sugarcane tips in three stages of maturation (9, 12, and 16 months), thereby, the experimental design was completely randomized (DIC), totaling 3 treatments with 3 replicates. Results of physical-chemical characterization were submitted to variance analysis (ANOVA) and, then the means were compared by the Tukey test (1% probability) using R software (R Development Core Team., 2011).

3. Results and Discussion

Results concerning the characterization of sugarcane heart raw and pickles are summarized in Table 1.

We can observe that both raw sugarcane hearts and pickles showed interesting nutritional results as an alternative food. Sugarcane heart raw did not show variations in physical-chemical composition between the different sugarcane maturations. The pH ranged from 4.4 to 4.5; acidity ranged from 0.34 to 0.35 g of citric acid.100 g-1 of the sample, these values are considered acceptable when compared to those found by Mao and Wang (2006) in their study of sugarcane juice storage which observed at harvest average total acidity of 0.47% citric acid. Other plant foods such as some varieties of orange and mandarin, studied by Couto et al. (2010), show an average value of 1.02% in citric acid.

All the parameters evaluated in the raw product are very similar to the results of the processed product; however, the protein contents of sugarcane heart pickles decreased, and probably soluble proteins may have been solubilized and lost by leaching during processing.

Sugarcane heart can be an interesting source of protein, in addition, it was verified that this product does not have high amounts of lipids or carbohydrates, resulting in low caloric value. Azzini et al. (1992), studying sugarcane heart found results close to those found in this study for sugarcane heart pickles in the parameters of proteins (2.1%), lipids (0.5%), and carbohydrates (2, 16%). We must consider several aspects when comparing the results because there are influences from many factors like farming practices, species, selected variety, planting site and, methodology used.

Table 1. Physical-chemical analyses (pH, total acidity, moisture, ashes, proteins, lipids, carbohydrates, and energy value) of sugarcane heart raw and pickles in three different stages of maturation (9, 12, and 16 months).

Analyses	Raw			Pickles		
	9	12	16	9	12	16
pH	4,4	4,4	4,5	4,4	4,5	4,5
TA (g of citric acid. 100 g^{-1})	0,35	0,34	0,35	0,48	0,46	0,46
Moisture (%)	91,3	90,9	92,2	93,0 b	93,2 b	94,5 a
Ashes (%)	2,7	2,6	2,4	2,0	2,0	1,8
Proteins (%)	1,9	1,9	1,2	1,0 a	1,1 a	0,5 b
Lipids (%)	0,3	0,3	0,2	0,1 b	0,1 b	0,3 a
Carbohydrates (%)	3,5	4,7	3,7	4,1 a	3,7 a	2,7 b
Energy Value (Kcal.100g^{-1})	24,9	29,4	21,1	21,6 a	20,8 a	15,5 b

Means followed by different letters in line differ statistically from each other by the Tukey test p≤0.05). Caption: TA: total acidity.
Source: Author's elaboration.

Hiane et al., (2011) which analyzed pickles of guarirobeira palm tree (*Syagrus oleracea* (Mart.) J. Becc.) raw and cooked, found close results for the average protein content (1.2%), being lower when compared to our values were equal to 2%. The average lipid content of guariroba pickles was 0.44% in the raw product and 0.24% in the processed product a value very similar to that obtained in our study (0.3%), but the ash content average in guariroba (approximately 0.8%) was lower than that obtained in our study, which averaged 2%.

For sugarcane heart pickles pH, total acidity, and ashes content did not differ according to the different sugarcane maturations tested in this experiment. pH ranged from 4.4 to 4.5; the acidity of 0.46 to 48 g of aq. citric acid.100 g^{-1} sample and the ash 1.8 to 2.0%. However, the moisture, protein content, lipid content, carbohydrate content, and energy value were different among the evaluated maturations.

Pickles produced from sugarcane with lower maturation time (9 and 12 months) were nutritionally superior when compared to the one that stayed the longest in the field (16 months), the results of moisture prove this fact when they presented lower in the maturation 9 and 12 months (93 and 93.2%, respectively), against 94.5% of maturation 16 months; in the case of protein, carbohydrate, and energetic value, the pickles from sugarcane with lower maturation time (protein: 1.0 and 1.1%; carbohydrates: 4.1 and 3.7%, energy value: 21.6 and 20.8 Kcal.100g^{-1} of the sample, in 9 and 12 months, respectively) were nutritionally superior to the pickles of higher maturation time (proteins: 0.5%, carbohydrates: 2.7%, energy: 15.5 Kcal.100g^{-1} sample, 16 months.

The sugarcane heart pickles have a high nutritional content which justifies further studies such as the presence of antioxidant activity compounds or mineral specification and quantification, as well as to test sugarcane heart pickles addition in gastronomic recipes as a form of value aggregation.

4. Final Considerations

Brazil is the world's largest producer and exporter of sugarcane according to data from Sugar Cane Industry Union (UNICA, 2022). Sugarcane is the crop that most generates waste in the country, according to a survey by the Institute of Applied Economic Research (IPEA, 2016).

This crop has reached a prominent role in the agribusiness sector and is recognized as one of the most important raw materials in the present, given the production numbers, either through the high production of hydrated alcohol or ethanol,

sugar, cachaça, bioenergy for ovens and boilers and the supply of raw materials for food such as rapadura and garapa, products of great importance in the food and economic subsistence of many regions of the country.

Environmental management systems implementation in sugarcane processing plants establishes the need for management awareness prioritization and prediction of human, financial, and material resources through attribution of environmental, social, and economic responsibility. Sugarcane by-products considered as the most used wastes are sugarcane bagasse, used as a food source for ruminants or as fodder and, also as fiber alternatives for reinforcement of fiber cement and concrete. Ashes from sugarcane bagasse have the potential to be used as a mineral addition, replacing part of the cement in mortars and concretes. Vinasse, which is generated in the distillation phase, is a sugar and alcohol industry by-product with high content of organic matter, potassium, calcium, and sulfur and, with much used in the fertirrigation.

As has been said, some by-products from sugarcane cultivation can be obtained and harnessed. Sugarcane bagasse and vinasse are already applied directly as raw materials in several economic segments of the alcohol and agribusiness industry. Sugarcane tips commonly left in the field as fodder material and incorporated into the soil as organic matter are discarded because they contain a high concentration of polyphenoloxidase (PPO) enzyme, whose properties react with phenolic compounds interfering and changing the color of sugarcane juice in industrial process and production and development of sugar.

Few studies on the potentials of sugarcane tips were carried out aiming at human consumption, except those that characterize their protein values, fibers, sugars, and cyanide acid. Collection and management of sugarcane residue left in the field after the harvesting process, as well as the processing of this residue in pickles, provides the alternative promotion in the economic production of inputs for use in pies, quiches, and risolis made in small-scale and/or medium-scale production, taking into account the income generation needs of small farmer or family farmer from Paranapanema region.

Low investment is required since the process includes a manual collection of waste, and processing can be done with common kitchen utensils and equipment, such as cookware, stove, freezer, or refrigerator, and utensils such as plastic basins, knives, pickers, sieves, and wrapper under vacuum. Considering that the residue of sugar cane is currently left in the field, the sugar cane pickles commercialization market can be a source of food and income in rural properties.

Based on the research carried out, it can be concluded that production protocols for obtaining sugarcane heart pickles were developed satisfactorily with food safety and hygiene allowing an option to increase the income of small farmers through the reuse of production residue from rural areas, as well as reduction this crop culture environmental impact. Pickles prepared with sugarcane heart in the shortest maturation (9 and 12 months) presented higher nutritional quality when compared to that who stayed longest in the field (16 months). Sugarcane heart physical-chemical characteristics are maintained after pickles processing. We can say that there is an application possibility of sugarcane heart for human feed.

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