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Technological utilization of *Bactris setosa* mesocarp flour as a neurotransmitter stimulant

Aproveitamento tecnológico da farinha do mesocarpo da *Bactris setosa* como estimulante neurotransmissor

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ABSTRACT

Difficulty in maintaining focus on tasks, motor agitation, impulsivity, and lack of attention are classic symptoms of attention deficit hyperactivity disorder (ADHD). Thus, the research aims to evaluate the chemical and nutritional effects of *Bactris setosa* (tucum) flour in different foods, further investigating whether these effects involve oxidative metabolism in the stimulation of neurotransmitter cells. The flour from the pulp of the tucum mesocarp was subjected to analysis of its physicochemical and nutritional aspects. The tucum pulp showed a yield of 25%, characterized by high levels of lipids, acetylcholine, vitamin C, B1, B5, and B6, zinc and calcium minerals, and a concentration of β-carotene, as well as being a source of fiber and carbohydrates. In the nutritional analyses, in 100g of tucum pulp flour, the following were found: energy 262 Kcal, carbohydrates 26.2g, proteins 2.1g, lipids 14.2g, fibers 12.2g, calcium 45.3mg, vitamin B1 36.7mg, vitamin B2 15mg, and vitamin B5 12.3mg. Therefore, further studies are necessary to verify whether diets with other proportions of *Bactris setosa* (tucum) used in supplementation could have beneficial effects on attention deficit.
Keywords: Attention deficit; Acetylcholine; Learning; Amazônia.

RESUMO

Dificuldade para manter o foco nas atividades, agitação motora, impulsividade e falta de atenção são os sintomas clássicos do transtorno de déficit de atenção e hiperatividade. Assim, a pesquisa tem como objetivo avaliar o efeito químico e nutricional da farinha da *Bactris setosa* (tucum) em diferentes alimentos investigando adicionalmente se tais efeitos envolvem o metabolismo oxidativo no estímulo às células neurotransmissora. A farinha da polpa do mesocarpo do tucum foram submetidos à análise dos aspectos físico química e nutricional. A polpa do tucumã demonstrou rendimento de 25%, caracterizado por elevados teores lipídico, acetilcolina, vitamina C, B1, B5, e B6, minerais zinco e cálcio, e de concentração de β-caroteno, fonte de fibras e carboidratos. Nas análises nutricionais em 100g de farinha da polpa de tucum foram encontrados energia 262Kcal, carboidratos 26,2g; proteínas 2,1g, lipídeos 14,2g, fibras 12,2g, Cálcio 45,3g, Vitamina B1 36,7mg, Vitamina B2 15mg, Vitamina B5 12,3mg. Desta forma, estudos complementares fazem-se necessários para verificar se dietas com outras proporções do *Bactris setosa* (tucum) utilizados na suplementação poderiam ter efeitos benéficos no déficit de atenção.

Palavras-chave: Déficit de atenção; Acetilcolina; Aprendizagem; Amazônia.

INTRODUCTION

There are various definitions from different authors regarding the term "learning difficulty and neurotransmitter stimuli," but Menezes et al. (2016) considers that before labeling a student with difficulty, one should seek to understand the supposed causes of this abnormality, differentiating between the influence of factors related to pedagogical practice or socio-economic conditions and a pathology that may be determining the observed situation.

Another condition associated with learning difficulties is childhood depression. In children aged 6 to 12 years, depressive mood can already be verbalized and may be reported as sadness, irritability, or boredom. Such patients may exhibit poor academic performance, leading to school refusal and reports of poor concentration, often associated with other depressive symptoms. These problems are often related to the quality of the food consumed (HAYES & HOFMANN, 2020).

All our sensations, feelings, thoughts, motor and emotional responses, learning and memory, the action of psychoactive drugs, the causes of learning deficits, and any other function or dysfunction of the human brain could not be understood without knowledge of the fascinating process of communication between nerve cells (neurotransmitters). Neurons need to continuously gather information about the internal state of the organism and its external environment, evaluate this information, and coordinate activities appropriate to the situation and current needs of the individual. This is essentially accomplished through neurotransmitter impulses. A nerve impulse is the transmission of a coded signal from a given stimulus along the neuron membrane, starting from its point of application. Nerve impulses can pass from one cell to another, creating a chain of information within a network of neurons (RLUO, 2021).

Two types of phenomena are involved in neurotransmitter impulse processing: electrical and chemical. Electrical events propagate the signal within a neuron, and chemical events transmit the signal from one neuron to another or to a muscle cell. The chemical process of interaction between neurons and between neurons and effector cells occurs at the neuron termination, in a structure called a synapse. Approaching the dendrite of another cell (but without material continuity between the two cells), the axon releases chemical substances called neurotransmitters, which bind to the chemical receptors of the next neuron and promote excitatory or inhibitory changes in its membrane, linked to its actions on the chemical process of food (KOCH & SEGEV, 2000).

Therefore, neurotransmitters enable nerve impulses from one cell to influence nerve impulses in another, allowing the cells of the brain to "communicate with each other," so to speak. The human body has developed a large number of these chemical messengers to facilitate internal communication and signal transmission within the brain. When everything functions properly, internal communications occur without us even being aware of them (GRACIANI et al., 2023). Understanding synaptic transmission is the key to understanding the basic operations of the nervous system at the cellular level. The nervous system controls and coordinates bodily functions and enables the body to respond and act on the environment. Synaptic transmission is the key process in the interactive action of the nervous system for learning.

When neurotransmitters fail to connect with each other, dysfunction in motor coordination is observed, occurring due to various factors, including poor food quality and a deficiency of nutrients that stimulate neurotransmitters. In light of the above, the research theme is the study of the nutritional and chemical effects of *Bactris setosa* flour to stimulate neurotransmitter production, with the objective of evaluating the chemical and nutritional effects of *Bactris setosa* (tucum) flour in different foods, additionally investigating whether such effects involve oxidative metabolism in neurotransmitter cell stimulation.

MATERIAL AND METHODS

Research Location

The fruit collection took place in the municipalities of the Northern State of Tocantins (Pico do Papagaio) during the ripening period of November and December. The Bico do Papagaio microregion is one of the microregions in the Brazilian state of Tocantins, belonging to the Western mesoregion of Tocantins. Its population was estimated at 208,388 inhabitants in 2016 by IBGE and is divided into 27 municipalities. It covers a total area of 15,767.856 km².

Research Design

The research was planned according to the focus of the problems and possible solutions (hypotheses), where variables aimed to differentiate the challenges faced by the student community and their resolutions. The methods and techniques used in the project were based on literature, documents, observations, laboratory experiments (study of tucum's active principles, microbiological, physicochemical, and nutritional studies), sensory analysis of foods, filming, and photographs that served as a basis for investigating the results. Observation and practice methods and techniques were outlined in experimental research. Physicochemical, active principles and nutritional analyses took place in the Biochemistry, Microscopy, and Dietetics laboratories at the State University of the Tocantina Region of Maranhão - UEMASUL.

Collection Methods

The fruits were collected from the ground after natural falling and/or directly from the palm tree. Before starting the fruit collection, palm trees were assessed for the presence of bird nests, bees, wasps. Up to 50% of the fruits from the same palm tree were collected.

Materials for Fruit Collection

- Hooks
- Pruners
- Ladders
- Straw baskets

Raw Material

The fruits of *Bacris setosa* Mart were collected from tucum palm plants and coded. Whole fruits were transported to the UEMASUL Laboratory, where they were selected, discarding those showing signs of deterioration. After selection, the fruits were rinsed under running water and then immersed in water at a temperature of 60ºC for 15 minutes to soften the mesocarp. Subsequently, the fruits were pulped using a stainless steel manual pulper, commonly known as a "beater," containing an internal shaft with "paddles." The obtained pulps were packed in polyethylene plastic bags and subjected to freezing at a temperature of -18ºC; they were then processed into flour.

Flour Production

First Step:

Firstly, fruit cleaning. A sink brush with soap and running water was used, followed by hot water to sterilize the fruit's peel before opening.

Second Step:

Pulp extraction. A sanitized teaspoon was used to avoid seed contamination. It was carefully scraped to avoid damaging the embryo. It was then taken to a regular blender to be transformed into flour.

Chemical and Nutritional Analysis of Tucum Pulp (*Bactris setosa*) Flour

Chemical analyses were conducted, including pH determination by direct measurement using a potentiometer, total titratable acidity (TTA) following A.O.A.C. (1995), total sugars (TS) and reducing sugars (RS) following the EYNON-LANE method (A.O.A.C., 1984). Non-reducing sugar (NRS) content was obtained by the difference between TS and RS; starch content followed the EYNON-LANE method (A.O.A.C., 1984), and ascorbic acid content followed the BENASSI method (1990). For pH determination, 5g of the sample were diluted in 200mL of distilled water and homogenized in a blender. Principal component analysis was processed using the CRUZ (2001), utilizing two principal components from the correlation matrix. This analysis orders genotypes according to the two principal components (CP1 and CP2) and identifies the importance of each variable.

Food Productions Using Tucum (*Bactris setosa*) Flour

Thirty kilograms of raw tucum pulp (*Bactris setosa*) were used, dried in a sterilization and drying oven - 1152 liters - Solid Steel at 30°C for one hour. Afterward, it was crushed in an Oster OLIQ610 1400 Full - 3.2L, 220V, 1400W, Black blender and sieved to produce flour ready for use in various foods. The yield after sieving was one kilogram and 300g. The produced foods included cakes, cookies, bread, and snacks.

Experimental Evaluation Methods of the Nutritional Activity of *Bactris setosa* Flour on Neurotransmitter Cell Stimulation

Initially, manometric and acid-base titration methods were used to evaluate nutritional activity. These tests quantified acetic acid produced during ACh hydrolysis. In the first case, hydrolysis occurred in $NaHCO_3/Na_2CO_3$ buffer, leading to acetic acid formation that reacted with the buffer base, releasing CO_2, measured by the Warburg/UEMASUL manometric apparatus. Acetic acid produced from ACh hydrolysis was also titrated with a 600 mg concentration solution of sodium bicarbonate in a 200ml water beaker, using acid/base indicators: phenolphthalein, phenol red, and bromothymol blue. This confirmed the enzymatic evaluation of AChE in neurotransmitter cells in the SynBio Molecular UEMASUL computerized system.

RESULTS

The tucum pulp (*Bactris setosa* Mart.) can be an alternative for the food industry in enriching products. In addition to providing a new option for consumers, it boasts high nutritional value, particularly in terms of carotenoid content, highlighting its antioxidant potential. The first of tucum's benefits that we should emphasize are its nutritional properties. The food is rich in antioxidants and serves as a source of essential nutrients for our body's functioning, including carbohydrates, fibers, calcium, potassium, magnesium, vitamin A, vitamin B1, B2, B5, and vitamin C.

Vitamin A is crucial for eye health, especially in low light, and for the production of pigments in the eye's retina. The nutrient also plays a role in the formation and maintenance of skin, teeth, skeleton, soft tissue, and mucous membranes, and may be necessary for reproduction and the breastfeeding process. In foods like fruits and vegetables, such as tucumã, vitamin A is present in the form of beta-carotene, an antioxidant substance. Each 100g portion of tucumã pulp contains 52mg of beta-carotene, and the presence of acetylcholine was also observed (Table 1).

Table 1. Nutritional chemical analysis per 100 grams of *Bactris setosa* (tucum) pulp flour.

Nutrients	Found Values
Lipids	14.2g ± *0.3*
Fiber	12.2g ± *0.2*
Calcium	45.3g ± *1.2*
Carbohydrates	26.2g ± *0.7*
Proteins	2.1g ± *0.1*
Vitamin A (antioxidant beta-carotene)	52mg ± *2.5*
Vitamin B1 (acetylcholine choline)	36.7mg ± *1.7*
Vitamin B2 (acetylcholine choline)	15mg ± *0.9*
Vitamin B5 (acetylcholine choline)	12.3mg± 0.5
Vitamin C	18mg ± *0.4*
Zinc	401 mg ± *23.9*
Energy	262Kcal ± *18.4*

Analyses conducted at the Biochemistry Laboratory of UEMASUL – 2023.
Source: Authors

Direct contact with steam did not alter the levels of moisture, lipids, and ash. The pulp exhibited higher energy value, protein, and fiber, attributed to the lower moisture percentage and higher lipid content in its composition. The lower the water content, the higher the content of other elements (Table 2).

Tabela 02. Centesimal composition and energy value per 100g of *Bactris setosa* (tucum) pulp during the storage period under refrigeration (4°C).

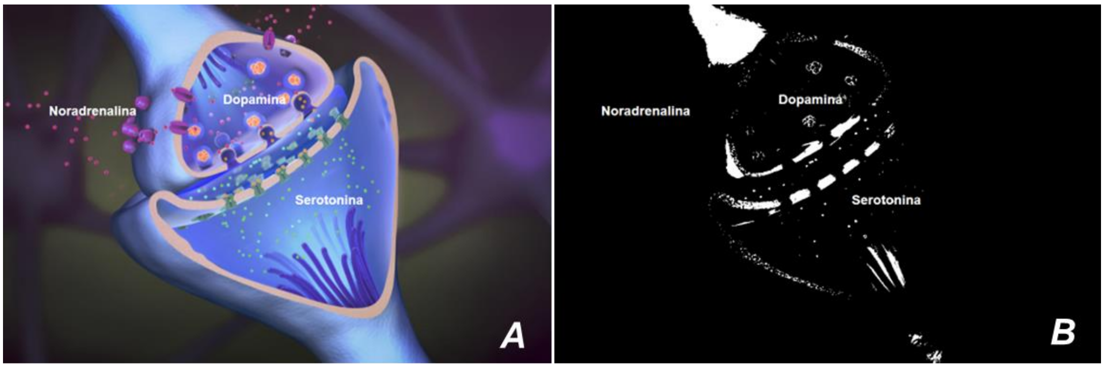
Constituent and Treatment	Found Values
Moisture (%)	55.46 ± *1.21*
Lipids (%)	31.09 ± *1.01*
Ash (%)	1.88 ± *0.01*
Fiber (%)	4.23 ± *0.02*
Proteins (%)	5.33 ± *0.03*
Carbohydrates (%)	2.01 ± 0.01
Energy (Kcal)	300.21 ± *2.6*

Tukey Test at a 5% significance level at the Biochemistry Laboratory of UEMASUL - 2023.

The minimally processed tucumã pulp stored at a temperature of 4°C for up to 20 days showed no significant changes in key attributes indicating the quality of the pulp, such as color, texture, and carotenoids. Thus, tucumã pulp contributed to maintaining its natural appearance, preserving freshness, and physical characteristics. Considering the convenience of ready-to-consume pulp with the retention of essential attributes for acceptability, the studied storage time allows for the commercialization and consumption of minimally processed tucumã pulp. When analyzing bread, cookies, and cake, they all received 100% approval from the participants. However, the rolled pastry received only 2% approval. In terms of appearance, the cake had the best result at 54%, while the cookie scored highest in taste at 38%. Regarding knowledge about the application of tucum flour in foods, only the cake reached 10%, while the other foods scored 2%.

Acetylcholine is a chemical substance that acts as a neurotransmitter, transmitting nerve impulses between cells of the nervous system. It is also associated with the transmission of impulses between the junctions of nerve and muscle cells, leading to muscle contraction. Acetylcholine is a quaternary ammonium base with a simplified formula ($CH_3COOCH_2CH_2N(CH_3)_3OH$), formed in the body in small quantities through enzymatic pathways. It is produced in the synaptic button (a swelling at the end of a nerve cell) and stored in vesicles until a new nerve impulse triggers its release at the junction of nerve cells (Figure 1). In biosynthetic analyses of ACh, the catalysis process by an acetyltransferase enzyme located at the terminal portion of the neuron was observed. After participating in the sensory test for five minutes, the participants reported feelings of happiness and well-being.

Figure 1 – Computer-simulated. A and B: Representation of the enzymatic action of AChE in Neurotransmitter Cells



Source: Molecular Biology Laboratory/UEMASUL.

DISCUSSION

Acetylcholine is an amine produced in the cytoplasm of nerve endings. Its precursor is a vitamin belonging to the B-complex, choline, obtained from diet or the degradation of acetylcholine by a specific enzyme (acetylcholinesterase), then transported back into the neuron from the extracellular fluid (HUBER, 2012). Antioxidants protect the body's cells against the effects of free radicals, substances known to contribute to the development of chronic diseases and premature aging. Acetylcholine is endogenously sourced, produced within our bodies from a substrate called choline derived from amino acids in our diet. Choline binds to acetyl-coenzyme A, forming acetylcholine through the enzyme choline acetyltransferase. Once formed, acetylcholine is stored in granules at the presynaptic level. For acetylcholine to take effect, it must be released from these storage granules and reach its site of action, the receptor, involving an increase in calcium permeability leading to acetylcholine release from presynaptic granules (BUTTRISS, 2000; ESTEVES et al, 2020; IKEDA et al., 2010).

The data showing higher fiber content in the pulp is important, as dietary fibers, found in plant tissues, are considered health-promoting foods and are currently included in the functional food group. They contribute not only to nutrition but also to regulating intestinal transit and preventing diseases (ARAUJO, 2018; BUTTRISS, 2000a; KELSAY, 1978).

There was a decrease in carbohydrate content with blanching. Jones and Beckett (1995) mention some negative points that can occur during blanching, such as the loss of vitamins, carbohydrates, flavonoids, and other water-soluble components. During pulp storage, there was a decrease in soluble solids content, indicating their utilization in respiration rather than production, as explained Huertas et al. (1999) and Fontenele et al. (2010). This decrease is due to mass loss during storage and the subsequent increase in organic acid concentration (ROURA et al., 2000). In this case, it is observed that people from the Northeast are not aware of the application of tucum flour as food, whereas respondents who knew about it are from Amazonas or have been to the state. In Amazonas, tucum pulp is widely used in cuisine. Therefore, sensory tests are important for human development, providing opportunities for people to explore new food possibilities through smells, textures, and flavors.

When acetylcholine reaches the receptor cell membrane, it binds to a specific site, causing depolarization and initiating a new impulse in nerve cells or a contraction in neurotransmitter cells. This process stimulates the chemical action of ACh, aiding communication between neurons in memory formation. ACh is also involved in muscle contraction processes associated with, for example, heartbeats and lung dilation in cardiovascular and respiratory systems, respectively. ACh, after synthesis, is released to interact with nicotinic and muscarinic receptors, generating a biological response. In other words, when ACh comes into contact with its specific receptors, it triggers a series of biochemical reactions in response to chemical stimuli (LEE et al., 2023; TAYLOR and BROWN, 2019).

In this case, serotonin played a role, often associated with the sensation of happiness, but this is not necessarily true. This neurotransmitter regulates mood, sleep, appetite, libido, anxiety, and dopamine, the true neurotransmitter of well-being, associated with the brain's reward system and the main neurotransmitter responsible for the pleasure sensation. Therefore, maintaining normal ACh concentration through a good diet is important for maintaining quality in normal processes related to memory consolidation, concentration, and learning.

CONCLUSION

Based on the presented results, it can be concluded that tucum pulp flour exhibited high in vitro antioxidant activity. The study revealed that the fresh tucum pulp has a high content of B-complex vitamins (acetylcholine), elevated levels of beta-carotene (vitamin A), antioxidants, proteins, lipids, fibers, calcium, and zinc. During the research, it was observed that nerve cells in the brain communicate with each other through the release of chemical substances; these substances are called neurotransmitters. Thus, it is asserted that acetylcholine is an important neurotransmitter stimulator for memory. Individuals with memory deficits have low levels of acetylcholine in the brain. The analysis showed that enzymes called cholinesterases destroy acetylcholine in the brain. If their action is inhibited, it releases acetylcholine for communication between neurons.

Cholinesterase inhibitor drugs block or inhibit the enzymes from destroying acetylcholine when it passes from one cell to another (communication between nerve impulses). This means that acetylcholine, which is present in lower concentrations in people with memory deficits, is not destroyed as rapidly, leading to a greater possibility of passing to the next nerve cell. Cholinesterase inhibitors result in higher concentrations of acetylcholine, leading to increased communication between neurotransmitter cells, which, in turn, may temporarily improve or stabilize dementia symptoms (forgetfulness). Therefore, further studies are needed to investigate whether diets with different proportions of *Batris setosa* (tucum) used in supplementation could have beneficial effects on attention deficit. Additionally, research is required to explore potential beneficial effects of tucum on the control of acetylcholine and acetylcholinesterase in vivo, testing isolated carotenoids, phenolics, or other bioactive compounds from this species on metabolic parameters.

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