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PROTOCOLO DE PRODUÇÃO DA FARINHA DE ESTIPE DO COGUMELO SHIITAKE

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RESUMO: O objetivo deste trabalho foi realizar o protocolo de produção da farinha de estipe de cogumelo shiitake (*Lentinula edodes*), de forma a aproveitá-lo e tornar possível o subproduto na alimentação humana. Para o desenvolvimento da farinha de estipe, o processo seguiu com as seguintes etapas: congelamento lento dos talos de shiitake; descongelamento; higienização; resfriamento; branqueamento; corte; secagem; acondicionamento; armazenamento; moagem e peneiragem. Os resultados obtidos nas análises foram: umidade (5,62%); L* (31,77); ºHue (45º); Chroma (0,55); pH (5,90) e Aw (0,44). Por fim, no presente estudo, pode-se concluir que a farinha de estipe de cogumelo shitake apresentou baixa atividade de água, mostrando ser um produto com estabilidade microbiológica, ligeiramente escura de acordo com seu teor de luminosidade, baixo teor de umidade e pode ser recomendada na alimentação.

Palavras chaves: píleo; processamento; produção.

PROTOCOL FOR PRODUCING SHIITAKE (Lentinula edodes) STYLE FLOUR

ABSTRACT: The objective of this work was to develop a production protocol for the flour of the shiitake mushroom Lentinula edodes to reuse it and make it a possible byproduct in human food. For the development of the shiitake flour, the process involved the following steps: slow freezing of the shiitake stalks; thawing; hygiene; cooling; blanching; cutting; drying; packaging; storage; and grinding and sieving. The results obtained in the analyses were as follows: humidity (5.62%); L* (31.77); °hue (45°); chroma (0.55); pH (5.90) and Aw (0.44). Finally, in the present study, the flour from the shiitake mushroom stipe flour presented low water activity, indicating that the flour is a product with microbiological stability, is slightly darker in terms of luminosity, has low moisture content and can be recommended for use in food.

Keywords: pileus; processing; production.

1 INTRODUCTION

Mushrooms, thousands of years ago, began to be appreciated in Eastern and European cuisine because of their high nutritional value and medicinal treatments. Its global production has increased in recent years, reaching just over 10 million tons in 2017, five times greater than that produced in 1990 (Faostat, 2017). In Brazil, an increase in mushroom production has also been observed due to the current growing demand from the population and the popularization and growth of oriental restaurants in the country (Associação Nacional dos Produtores de Gugumelos, 2013).

Currently, the Ministry of Industry, Foreign Trade and Services (2023) is working on calculating national production data. After a hiatus in the survey during the pandemic years, projections for the year 2023 pointed to

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production of up to 14 thousand tons. The dollar value of mushroom and truffle production in 2019 was 44,653.506; in 2020, it was 43,774.112; in 2021, it was 500,445.74; and in 2022, it was 465,148.03 (Faostat, 2024).

The agro-industrial branch aimed at mushroom production is called fungiculture, a species of fungi also known as macrofungi (Martínez-Ibarra; Gómez-Martín; Armesto - López, 2019). Among the known mushrooms or fungi that produce fruiting bodies, 50% are edible, 18% are medicinal, 10% are poisonous, and 22% still have properties of commercial interest; however, these properties have not yet been established (Floudas *et al*., 2012).

Shiitake cultivation can be divided into two types: rudimentary, which is carried out on wooden logs, and synthetic, which is carried out on synthetic substrates. In the form of logs, which are currently the most common, cultivation is carried out on eucalyptus wood, and synthetic substrates are made from agricultural residues and other types of waste, such as rice bran, wood dust, wheat bran, corn straw, gypsum, lime, and limestone (Urben, 2017).

The large mushroom producers in Brazil are concentrated in the state of São Paulo, where approximately 500 producers generate R$21 million reais, but production also occurs in the states of Minas Gerais, Paraná, Rio de Janeiro, Brasília, Rio Grande do Sul, Bahia and Pernambuco. Among the producers in the state of São Paulo, the cities that stand out the most are Mogi das Cruzes, Pinhalzinho, Ibiúna, Sorocaba, Salto, Cabreúva, Juquitiba and Valinhos. According to the National Association of Mushroom Producers (2013), there are more than 300 mushroom producers in the country, as the majority of them are micro- and small family farmers (National Association of Mushroom Producers, 2013; Zanatta, 2020).

Agaricus stands out. *Bisporus* (Paris champignon), *Lentinula edodes* (shiake) and *Pleurotus* (shimeji or hiratake) (National Association of Mushroom Producers, 2013). The cultivation of the shiitake mushroom began in Brazil in the early 1990s, and currently, its production has significantly increased because of the viability of its cultivation in small areas, which currently occupies second place in production in relation to all mushrooms cultivated worldwide (Maciel, 2012).

Mushroom reproduction can occur sexually or asexually, with sexual reproduction carried out through spores and asexual reproduction carried out by the multiplication of any part of the fruiting body (Rosa, 2006).

Fungi play a major role in the ecosystem, as they have the ability to degrade agricultural production substrates, and these are the most significant microorganisms involved in the decomposition of organic raw material due to their characteristic degradative action. This occurs due to the production of extracellular enzymes, mainly lignocellulose, which is important for the degradation of substrate components (Válazquez-Cedeño; Mata; Savoie, 2002).

As a consequence of the relevant increase in the production and consumption of mushrooms, there has been an increase in the volume of waste generated, resulting from the harvesting and processing stages, which are composed mainly of the stem (the base of the mushroom), which is generally discarded owing to its characteristics. unwanted sensory effects by consumers (Zhang *et al*., 2013), which represents 25–33% of the product's weight (Chou; Sheih; Fang, 2013). This results in volumes of 2.5 to 3.3 million tons of waste per year worldwide, which are discarded, representing an environmental problem, in addition to not generating economic gains for the producer or industry (Zhang *et al*. , 2013).

Shiitake mushrooms are known for being foods with high nutritional value, with high fiber content (41.92%), protein content (18.98%) and low lipid content (4.39%) (Furlani; Godoy, 2007). Furthermore, they present a series of bioactive properties, such as antifungal, antimicrobial (Hearst *et al*., 2009), and antitumor (Finimundy *et al*.). 2013) and antioxidant activity (Kitzberger *et al*., 2007). They are also known for being flavor enhancers, as they contain compounds that provide umami flavors (Poojary *et al*., 2017).

Edible mushrooms, in turn, because they have these components that benefit the body, can contribute to reducing malnutrition or add to a good diet because of their high nutritional value (Moura, 2008).

Given the high nutritional and functional value of the mushroom, it is expected that its stem has a similar composition, which indicates that it is a potential material for studying its reuse as an ingredient in different foods, providing waste with an environmentally correct destination. This would make the activity even more sustainable, since in the production of mushrooms, the substrates used are mostly agricultural and agro-industrial residues, such as straw, sawdust, sugarcane bagasse, wheat bran and rice bran, which, after use, can also be used to fertilize vegetable gardens and plantations (Furlani; Godoy, 2007). Therefore, the development of alternative flours rich in proteins and fibers adds functional characteristics to these products and could be used in the preparation of bakery products, pasta and cereal bars (Sarinho; Cavalcanti; Oliveira, 2021).

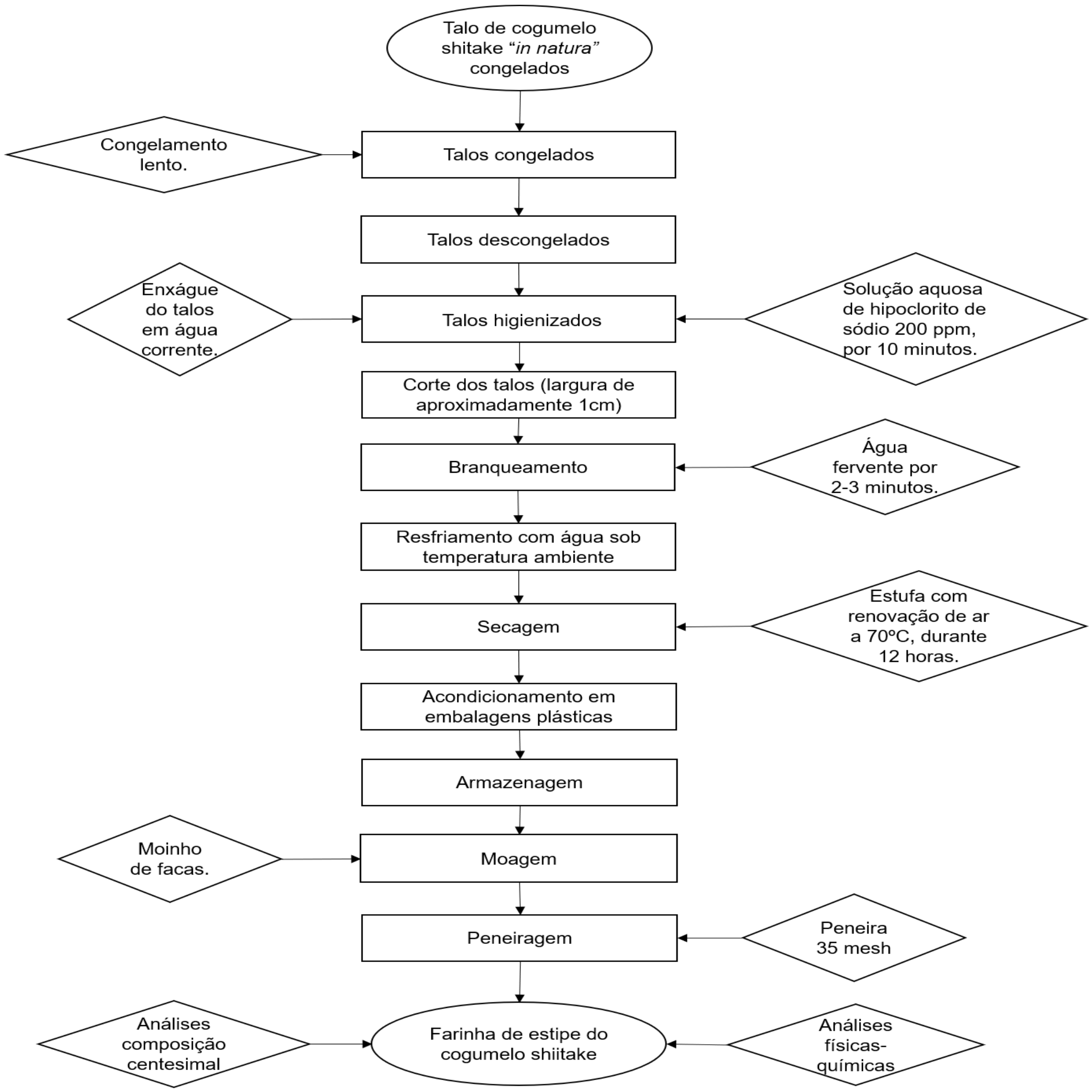
Considering the nutritional, functional and sensorial potential of the shiitake mushroom, studies on the chemical composition of its byproduct, the stipe, are important to characterize the material and develop future applications of this agro-industrial residue in the food industry, representing an economic alternative for producers and agro-industries, nutritional and health for consumers and sustainability for the environment. This work aims to develop a production protocol for shiitake mushroom stipe flour (*Lentinula edodes*) to reuse it and make the byproduct possible for human consumption.

2 MATERIALS AND METHODS

2.1 Material

The samples used to develop the work were shiitake mushroom stems donated in July 2020 by the company Fungibras, which is located in Botucatu–SP. To develop the shiitake stalk flour, the steps in the protocol in Figure 1 were followed.

Figure 1. Shiitake stalk flour production protocol



Source: Prepared by the author (ABNT – Nbr 12607) (2024).

2.2 Methods

The collected samples were frozen via the slow freezing process (-18°C) and transported in thermal boxes to UNESP - Botucatu, where they were kept in a freezer at -18°C until use. The samples were thawed and sanitized in an aqueous solution of 200 ppm sodium hypochlorite for 10 minutes, followed by rinsing in good-quality drinking water. Then, the samples were cut (width of approximately 1 cm) and blanched with boiling water (100°C ± 1) for 2–3 minutes, followed by cooling with ice water (Maray; Mostafa; El-Fakhrany, 2018) to prevent enzymatic browning promoted mainly by tyrosinase and catecholase enzymes (Moda *et al.*, 2005). Drying was carried out in an oven with air renewal at 70°C for 12 hours. All dehydrated material was packed in plastic packaging, stored in a dry, ventilated place and protected from light. Grinding was carried out in a Tecnal knife mill model TE-650/1, and subsequently, the byproducts were sieved (35 mesh). To calculate the yield of the stems after drying, Equation (1) was used.

%Yield = (weight of wet vines – weight of dry vines) × 100 (1)

2.2.1 *Determination of hydrogen potential* (pH)

pH readings were performed on a bench pH meter equipped with a glass electrode (Micronal; model TEC-5) via the method described by the Association of Official Analytical Chemists (1995). A total of 10 g of shiitake mushroom stipe flour was weighed in a 250 ml beaker, 100 ml of distilled water was added, and the pH of the solution was measured. The analysis was performed in triplicate.

2.2.2 Determination of water activity

Water activity was determined in triplicate, with samples stabilized at 25°C, via the AquaLab 4TE analyzer. This analysis was performed in triplicate.

2.2.3 Instrumental color determination

To determine the instrumental color of mushroom stipe flour, a portable colorimeter device (Minolta Chroma Meter, Model CR-400) with the following parameters was used: L* (brightness), varying from 0 (black) to 100 (white); a* (red/green intensity); b* (red/green intensity) yellow/blue) from the CIELab system; and D65 illuminating source calibrated on standard white porcelain with Y=93.7, x=0.3160 and y=0.3323 (Minolta, 1998). Color determination was carried out in triplicate.

The hue angle (hue angle) is the value in degrees corresponding to the three-dimensional color diagram, starting on the +a axis, with 0° (+a) corresponding to red, (+b) 90° corresponding to yellow, 180° (-a) corresponding to green and 270° (-b) corresponding to blue. Chroma is represented by C*, which defines the intensity of the color; the chroma value is 0 in the center and increases according to the distance from it (Minolta, 1998). The numerical values of a* and b* were converted into hue angles and chroma values (which are the variables that best represent the color of the shiitake mushroom stipe flour), according to Equations 2 and 3.

$$Hue_{ab} = tan^{-1}\left(\frac{a}{b}\right) \quad (2)$$

$$C^{*} = \sqrt{((a^{*})^{2} + (b^{*})^{2})} \quad (3)$$

3 RESULTS AND DISCUSSION

The results obtained from the dry moisture analysis of the shiitake mushroom stipe flour are shown in Table 1. The results obtained from the luminosity analysis (L*), *hue angle* (Hue), chroma, pH, and water activity (Aw) of the shiitake stem flour are shown in Table 2. The stem yield after drying was 11.9%.

Table 1. Moisture (%) of shiitake stipe flour

Component	%
Humidity	5.62 ± 0.78

Mean ± standard deviation. n=3.

The result obtained from the humidity analysis was 5.62%. Since the initial sample used in this study was dried with mushroom stipe flour, the moisture content was expected to be low. According to the work of Cunha *et al*. (2011), the evaluation of the composition of shiitake mushrooms dried at 55°C revealed a moisture content of 11.34% in the product obtained by the producer in Brasília and 11.13% in the mushroom from the producer in Mogi das Cruzes. In another work, Lira, Carvalho and Oliveira (2016) reported a value of 10.24% in shiitake mushrooms dried at 60°C for 24 hours. Therefore, we can observe that the results in the literature are above what was obtained in this work. The discrepancies in moisture content between samples may be related to the fact that this study evaluated only the mushroom stipe, whereas the literature studies used the entire mushroom.

Furthermore, there are variations in drying time and temperature between studies, which influence the drying intensity and, consequently, the final moisture content of the samples. According to Mattila *et al*. (2001), one of the most important factors in regard to nutritional value is the moisture content, which influences the amount of dry matter, that is, the content of the other components of the material under study. The author also stated that other environmental factors can affect the amount of moisture in mushrooms, such as temperature, relative humidity and pH, which explains the difference between the results presented in this work and the literature on the subject.

Table 2. Luminosity (L*), hue angle (°), chroma, pH, and water activity (Aw) of shiitake stipe flour

Parameters	**Shiitake stem**
L*	31.77 ± 0.36
° *Hue*	45th
Chroma	0.55 ± 0.01
pH	5.90 ± 0.06
Aw	0.44 ± 0.012

Mean ± standard deviation. n=3.

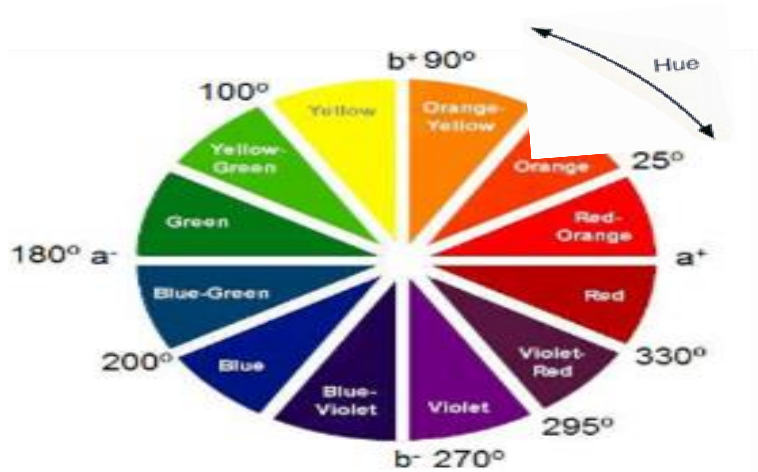
The results obtained for instrumental color show that the L* parameter, which refers to luminosity, was 31.77. A slightly greater value (41.74) was reported for commercial shiitake stem flour in a study by Lin *et al*. (2008). Lira (2017) reported a value of 77.27 for the whole shiitake mushroom; that is, the flour developed in the present work is darker than that developed by this author. This darkening possibly occurred because this was the study of the entire mushroom in the literature and because the time used to dry the Lira (2017) sample was longer (24 hours).

The hue angle was 45°, and according to Figure 2, the hue angle was orange, and the intensity was 0.55, as shown in Figure 3. Figure 4 shows a photo of the finished flour.

The color parameters are related to the part of the mushroom evaluated, as well as the drying intensity, which can affect the color of the final product. In this sense, the application of mushroom stipe flour in products can result in different colors. traditional, which can lead the consumer to be influenced by color when purchasing.

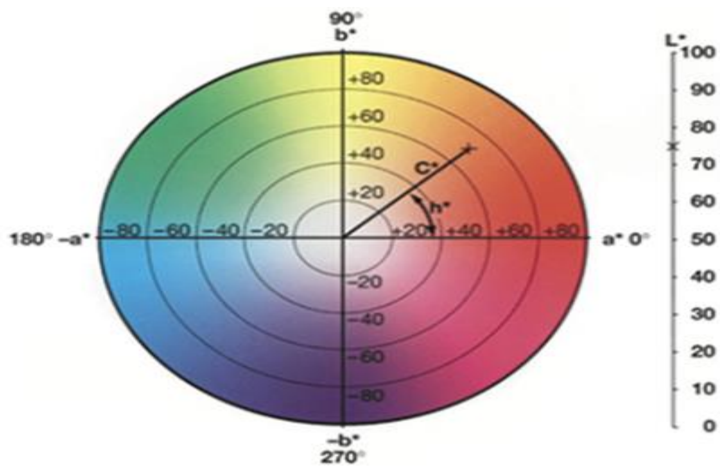
The pH value obtained in this work was 5.90, which is close to that reported in the literature (6.12) (Lira; Carvalho; Oliveira, 2016). However, compared with data from Cunha *et al*. (2011), the pH of the shiitake mushroom sample produced in Brasília was 6.52, and that of the one produced in Mogi das Cruzes was 6.66. This variation in pH, in contrast to the results of this work, may be related to different factors, mainly the type of substrate used in cultivation, or may be related to the concentration of acids in the drying process and the part of the mushroom analyzed (stem) (Cunha *et al*., 2011).

Figure 2. Color circle



Source: Nogueira *et al*. (2016).

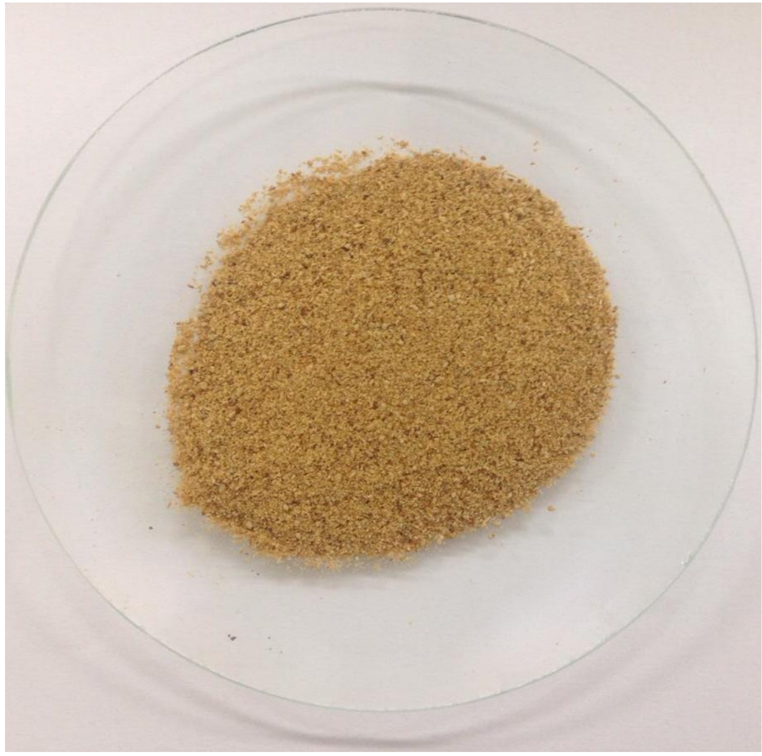
Figure 3. L*C*h° color space



Source: Adapted from Ferreira and Spricigo (2017).

The water activity found in this work was 0.44. According to Lira, Carvalho and Oliveira (2016), the value obtained for shiitake flour was 0.54, and in another work, Cunha *et al*. (2011) reported a value of 0.23. These results indicate that the products are microbiologically stable at room temperature, as they present a water activity lower than 0.6, which is considered limiting for the development of microorganisms (Lira; Carvalho; Oliveira, 2016).

Figure 4. Photo of finished flour



Source: Prepared by the author (2024).

4 CONCLUSION

Under the conditions under which this work was carried out, it can be concluded that mushroom stipe flour can be recommended for use in food. It has a low moisture content (5.62%) and low water activity (0.44%), is microbiologically stable at room temperature and is slightly dark according to its light content (L*) (31.77).

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