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THE WORLD MUSHROOM MARKET AND BRAZIL'S ROLE: INDUSTRIAL INTEGRATION AS A KEY FOR COMPETITIVENESS

Diego de Mello Conde de Brito[A], Carolina Lima Crivano[B], Cristiane Martins Cardoso[C], Marco André Alves de Souza[D]

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ABSTRACT

Purpose: In this article we presented the main aspects of world mushroom market emphasizing the major opportunities for Brazil producers.

Theoretical framework: A recent market research shows that it is foreseen to increase significantly from 2018 until 2026 with a compound annual growth rate of 6.41%. China is the major player in the world mushroom market and their products with low prices are gaining space in the Brazilian market resulting in problems to national producers.

Design/Methodology/Approach: The article was designed via bibliographic survey of international publications with scientific recognition using Scopus, Web of Science and Scholar Google. Books and recent news also were used as a source of information. Topics researched were mushrooms, world mushroom market, Brazilian mushroom market e the use of spent mushroom substrate (SMS) in industrial chain.

Findings: One of the most promising opportunities is the integration between agri-food industries and mushroom production via exchange of waste and spent mushroom substrate (SMS) in a circular economy model.

Conclusion: The use of SMS could be the key to reduce the cost of Brazilian mushroom production and, consequently increase its competitiveness, associated with a reduction of environmental impacts of the industrial activities.

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O MERCADO MUNDIAL DE COGUMELOS E O PAPEL DO BRASIL: A INTEGRAÇÃO INDUSTRIAL COMO A CHAVE PARA A COMPETITIVIDADE

RESUMO

Objetivo: O objetivo do artigo foi apresentar os principais aspectos do mercado mundial de cogumelos enfatizando as oportunidades mais relevantes para os produtores brasileiros.

Referencial teórico: Estudos recentes de mercado indicam uma perspectiva de crescimento significativo de 2018 a 2026 com uma taxa de crescimento anual composta de 6.41%. A China é o principal líder desse mercado e seus produtos com baixos preços tem ganhado espaço no mercado brasileiro, resultando em problemas para os produtores nacionais.

[A] *PhD in Chemistry, Biochemistry department, Universidade Federal Rural do Rio de Janeiro, Rio de Janeiro, Brazil. E-mail: diegobioquimica@hotmail.com Orcid: https://orcid.org/0000-0003-0521-4887*
[B] *Undergraduate in Biology, Universidade Federal Rural do Rio de Janeiro, Rio de Janeiro, Brazil. E-mail: carolina.crivano@gmail.com Orcid: https://orcid.org/0009-0006-9641-4276*
[C] *PhD in Biochemistry, Biochemistry department, Universidade Federal Rural do Rio de Janeiro, Rio de Janeiro, Brazil. E-mail: cardosocristiane2006@gmail.com Orcid: https://orcid.org/0000-0003-4061-8561*
[D] *PhD in Chemistry, Biochemistry department, Universidade Federal Rural do Rio de Janeiro, Rio de Janeiro, Brazil. E-mail: decoerej1975@gmail.com Orcid: https://orcid.org/0000-0003-2173-3513*

Desenho/Metodologia/Abordagem: Para o desenvolvimento desse artigo foi realizado um levantamento bibliográfico onde foram analisadas publicações internacionais de reconhecimento científico, principalmente, a partir da pesquisa nos sites Scopus, Web of science e Google acadêmico, além de banco de dados de notícias recentes e livros. Os temas pesquisados foram cogumelo, mercado mundial de cogumelos, mercado brasileiro de cogumelos e uso de substrato pós-cultivo (SPC) de cogumelos na cadeia industrial.
Resultados: Uma das oportunidades mais promissoras é a integração entre a indústria agroalimentar (IAA) e a produção de cogumelos por meio do intercâmbio de rejeitos e substrato pós-cultivo de cogumelo (SPC) em um modelo de economia circular.
Conclusão: O uso de SPC pode ser a chave na redução de custos da produção brasileira de cogumelos e, consequentemente, proporcionar um aumento da competitividade dessa produção associada a uma redução dos impactos ambientais da atividade industrial.

Palavras-chave: Champignon, Shiitake, Shimeji, Substrato Pós-cultivo de Cogumelo (SPC), Cogumelos Comestíveis.

EL MERCADO MUNDIAL DE HONGOS Y EL PAPEL DE BRASIL: LA INTEGRACIÓN INDUSTRIAL COMO LA CLAVE PARA LA COMPETITIVIDAD

RESUMEN
Propósito: El objetivo del artículo fue presentar los principales aspectos del mercado mundial de hongos, enfatizando las oportunidades más relevantes para los productores brasileños.
Marco teórico: Estudios de mercado recientes indican una perspectiva de crecimiento significativo de 2018 a 2026 con una tasa de crecimiento anual compuesta de 6.41%. China es el principal líder en este mercado y sus productos de bajo precio ganaron espacio en el mercado brasileño, generando problemas para los productores nacionales.
Metodología: Para el desarrollo de este artículo se realizó una revisión bibliográfica donde se analizaron publicaciones de reconocimiento científico internacional, principalmente de la investigación en sitios académicos Scopus, Web of Science y Google, además de base de datos de noticias actualizadas y libros. Los temas investigados fueron los hongos, el mercado mundial de hongos, el mercado brasileño de hongos y el uso de sustrato postcultivo (SPC) de hongos en cadena industrial.
Hallazgos: Una de las oportunidades más prometedoras es la integración entre la industria agroalimentaria (IAA) y la producción de hongos a través del intercambio de residuos y sustrato postcultivo de hongos (SPC) en un modelo de economía circular.
Conclusión: El uso de sustrato postcultivo de hongos (SPC) puede ser la clave para reducir los costos en la producción de hongos en Brasil y, en consecuencia, proporcionar un aumento en la competitividad de esa producción asociada a una reducción de los impactos ambientales de la actividad industrial.

Palabras clave: Champiñón, Shiitake, Shimeji, Sustrato Postcultivo de Hongos (SPC), Hongos Comestibles.

INTRODUCTION

Mushrooms are fungi that in large part presents a saprophyte behavior, in other words, a recycler of organic matter in the ecosystems. These organisms are widely considered the premier recycler of the planet and are used by humans for edible and medicinal purposes (Stamets, 1993).

The per capita human consumption of mushrooms increased dramatically in the last decades mostly by the higher use in human nutrition combined with innovations in mushroom production techniques. This increase creates an industry valued at approximately $63 billion in 2013 (Royse, 2017).

China is the main producer of edible mushrooms in the world, but Brazil has an exciting potential in this market. With the acceptance and the positive perspectives of "*In natura*" mushrooms by consumers the Brazilian producers preserved only a small niche in the Brazil's market, invaded by Chinese mushrooms (Santos, 2018; Silva *et al*., 2018). The main reason for the success of Chinese mushrooms in Brazil is the low cost of production and, consequently, low final prices.

In this article we presented a brief overview of mushroom production in the world and the opportunities for Brazil. We conclude that the use of the spent mushroom substrate (SMS) could be an opportunity for industrial integration causing the reduction of production costs and environmental impacts. Thus, the SMS use can be a possibility for Brazilian mushroom producers for more competitiveness in this market.

THEORETICAL REFERENCE FRAMWEORK

Mushroom Production in the World

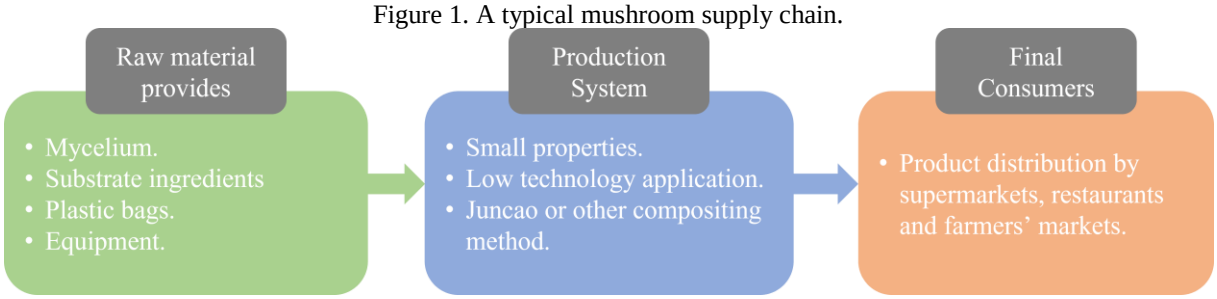
Mushroom are used by humans since paleolithic times and played a pivotal role in various moments of human history. A mushroom from genus Amanita was allegedly used by enemies to kill Giulio di Giuliano de' Medici, also known as Pope Clement VII, in 1534 (Stamets, 1993). On the other hand, the positive use of mushrooms is also common and, as an important source of nutrients, initiated in Japan in the middle of the 17th century. This country is the first that used primitive methods for shiitake (*Lentinula edodes*) cultivation aiming edible purposes. This method used the inoculation of shiitake mycelia in logs of several naturally occurring species of trees (*Quercus* and *Castanopsis*) in Japan (Yamanaka, 2011).

In 1928 a new cultivation method based on sawdust-substrate invented by Hikosaburo Morimoto for enokitake (*Flammulina velutipes*) production changed the history of mushroom market. This method based in a low-cost substrate and easily available in different regions of the world was gradually adopted for cultivation of other mushrooms species along the decades and became the opportunity for other counties to reach this market (Royse *et al.*, 2017; Yamanaka, 2011). This opportunity was best reached by China that is by far the first leader in the global mushroom market, however, other countries also significantly developed their productions.

Therefore, the world mushroom industry was established, and the supply chain developed follows the model detailed in **figure 1**. The common raw material utilized are substrate ingredients, mycelium, equipment, and other materials like plastic bags. In general,

the production system is performed in small properties using in a lot of cases family labor that shows low educational levels. Consequently, low technology application is observed in the productions (Azevedo *et al.*, 2014). In fact, the production of mushrooms occurs via composting, or a method based in the use plant wastes and plastic bags named Juncao (Vargas, 2011). The product distribution is made mostly by supermarkets that obtains a significant profit margin in this industry (Celik & Peker, 2009).

Figure 1. A typical mushroom supply chain.



Source: Azevedo *et al*. (2014); Banasik (2019).

In 2013, the world mushroom market was valued at $63 billion with edible mushrooms as the main component ($34 billion) largely produced by China that responds for 87% of total production of edible mushrooms (Royse *et al.*, 2017). This highly valued market shows an interesting and dynamic behavior along the last decades (Table 1). In late 80s *Agaricus bisporus* (Champignon) was the main cultivated mushroom produced in the world, but it changes dramatically in 1997. At this time, data showed that *Lentinula edodes* (Shiitake) occupied the first position and the *Pleurotus spp.* (Shimeji) cultivation almost doubled. In 2013, Champignon lost the position of most cultivated mushroom of the world for Shiitake. In fact, at this period shimeji and *Auricularia spp.* (Black ear mushroom) production was higher than the champignon production rate. Also, both mushroom species presented a significant increase in its production at each period evaluated (Chang, 1999). It could be a valuable information about the perspectives of world mushroom market in the next decades.

Table 1. World production of cultivated edible mushrooms.

Species	Representative name	1986	1997	2013
Agaricus bisporus	Champignon	56.2 %	31.8 %	15.0 %
Lentinula edodes	Shiitake	14.4 %	25.4 %	22.0 %
Pleurotus spp.	Shimeji	7.7 %	14.2 %	19.0 %
Auricularia spp.	Black ear mushroom	5.5 %	7.9 %	18.0 %
Volvariella volvacea	straw mushroom	8.2 %	3.0 %	5.0 %
Flammulina velutipes	winter mushroom	4.6 %	4.6 %	11.0 %
Others	----------	3.4 %	13.1 %	10.0 %

Source: Chang (1999); Royse *et al*. (2017)

According with the behavior of world production of cultivated edible mushrooms in the last decades we can forecast a high growth tendency for this market in the next future. From 1978 to 2013, data showed a 30-fold increase in this market while the population growth presented only a 1.7-fold increase (Royse *et al.*, 2017). Considering especially the world production of Shiitake, Chang (1999) cited that can be observed a consistent annual increase of 38.5%, from 1983 to 1997, that is an increase of 539.4% during this period. The authors also pointed that China production of shiitake was 9.4% of world production in 1983 but it reached 85.1% after 14 years.

However, the export of Chinese mushrooms presented a central problem when we are considering a promising niche of this market, the "*In natura*" segment. It is caused by the fact that mushrooms when in "*In natura*" form must be usually consumed in 7 days after the harvest. Thus, considering this market segment as the future tendency in the global market of edible mushrooms it opens an opportunity for domestic production, especially in countries like Brazil.

Brazil's mushroom market: history, status, and perspectives

In Brazil, the commercial production of edible mushrooms was started around 1953 with the arriving of Asian immigrants in the State of São Paulo, which became the main production center until nowadays (Bononi *et al.*, 1999). This production was initiated using family labor and low technology resources until 1986 when an Italian named Mr. Oscar Molena disseminate new techniques and that contributed to mushroom cultivation development in Brazil (Dias, 2010).

In the early XXI century, champignon, shiitake and shimeji are the most cultivated mushroom species in Brazil with pickled champignon as the major national product. However, in 2008 with the reductions of import tax barriers the pickled champignon from China overcame the national product and the producers from Brazil who were forced to search for alternatives (Santos, 2018). In the last years, a promising alternative for Brazilian mushroom producers is gaining more attention, the "*In natura*" niche market.

This niche market could be an important alternative because mushrooms imported from China cannot reach the Brazilian market when it is in "*In natura*" form. This scenario occurs because of the fresh product has around 7 days of shelf life and specific conservation requirements (Santos, 2018; Silva *et al.*, 2018). Furthermore, it does not have to be processed and can be marketed with lower restrictions by the Brazilian authorities than the pickled product

(Dias, 2010). Indeed, fresh mushroom consumption that is already a habit in various developed countries is recently helping to revitalize the Brazilian mushroom market.

Another special aspect of Brazilian mushroom market is the significant importance of culinary-medicinal *Agaricus blazei* Murrill (Royal sun agaricus or sun mushroom). This mushroom was discovered in city of Piedade (São Paulo state) by a grower named Furumoto and since then it has been significantly accepted in the Brazilian market and became one of the most cultivated mushrooms in Brazil (Dias *et al*., 2004).

Aiming to understand better the Brazilian mushroom market, research was made in 2013 and provided information about the main cultivated mushrooms and data about their production in Brazil (Table 2). Considering that the Chinese mushroom production reached about five million tons in 2013, the role of Brazil in this market must be developed.

Table 2. Brazil production of cultivated mushrooms "*In natura*"

Species	Representative name	Estimated production (Tons/ year)
Agaricus bisporus	Champignon	8.000
Pleurotus spp.	Shimeji	2.000
Lentinula edodes	Shiitake	1.500
Agaricus blazei Murrill	Royal sun agaricus or sun mushroom	500
Others	----------	50
Total	----------	12.550

Source: ANPC (2013).

Moreover, the perspectives about the global mushroom market indicates a high expansion and it can be an important opportunity for Brazil. Market research made by Fortune business insights (2018) indicates that global mushroom consumption was 12.74 million tons in 2018 and is projected to reach 20.84 million tons in 2026, with a compound annual growth rate of 6.41%.

This growing interest in mushroom consumption is largely because of the diffusion of its culinary use. Furthermore, recently positive nutritional values of mushrooms, due to its high protein levels combined with low levels of fat, anti-ROS, anti-tumoral and anti-bacterial activities has been consolidated (Negri, 2012; Orsine *et al*., 2012). According with Roncero-ramos and Delgado-andrade (2017) the mushroom consumption as part of daily diet can also help to treat and prevent chronic diseases in humans.

Thus, beyond its culinary appreciation mushrooms has been recently established as functional foods what can also contributes for the increase in its market in the future. However, even with the growth projections about the world mushroom market, the Brazilian product

shows a high production cost and, thus, does not show a competitiveness against the Chinese mushrooms.

METHODOLOGY

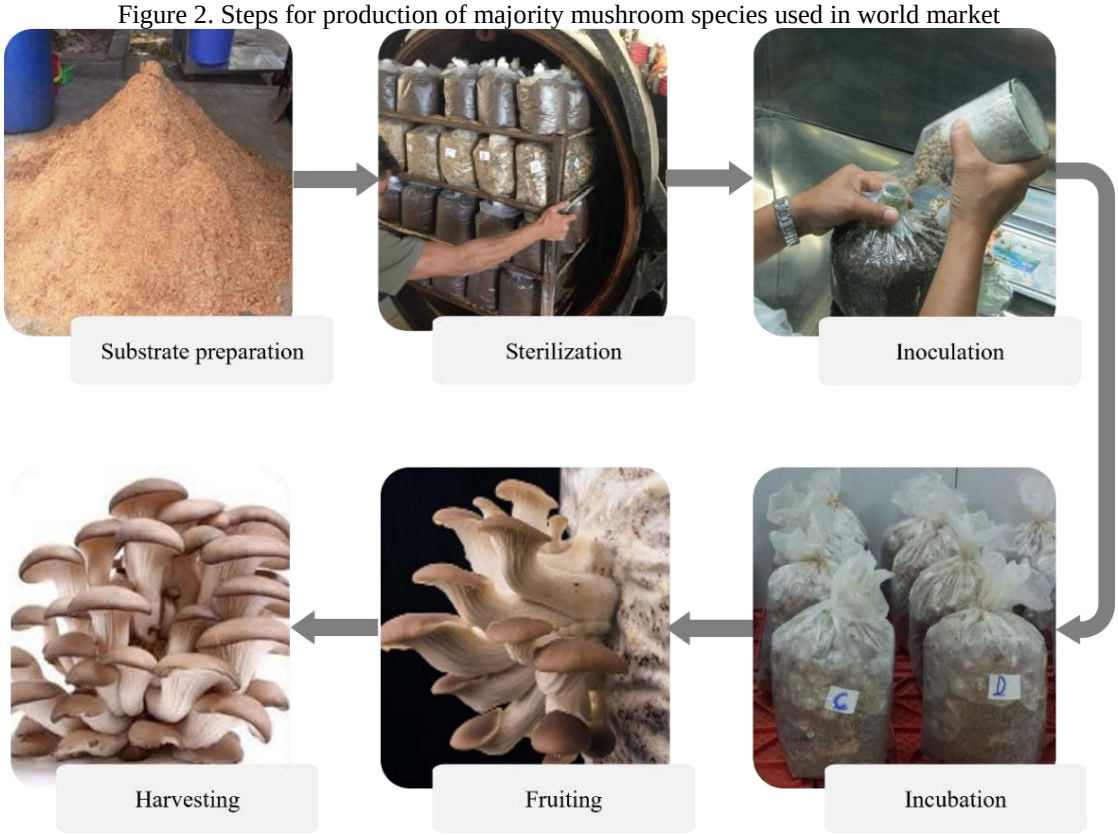
The article was designed via bibliographic survey of international publications with scientific recognition using Scopus, Web of Science and Scholar Google. For the research, the topics used were mushrooms, world mushroom market, Brazilian mushroom market and spent mushroom substrate (SMS). Only articles published after the year 2000 were considered for a detailed discussion of the mushroom industry and market.

The figures were developed using Power Point for Microsoft 365 and tables were designed using Word for Microsoft 365. After the data compilation, the main objective was identifying economical bottlenecks in the most common methods of mushroom production and the potential opportunities in its industrial chain to solve the problems presented.

RESULTS AND DISCUSSION

Although the steps of mushroom production are related to the specie considered the results obtained indicates that it commonly involves 6 phases: substrate preparation, pasteurization or sterilization, inoculation, incubation, fruiting and harvesting **(Figure 2)**. Thus, the mushroom production process starts with substrate preparation that uses sawdust, straw, and several types of husks (Nguyen, 2019). In Brazil, specifically, substrate preparation also uses commonly manure, soybean, and wheat meal (Azevedo *et al*.). In general, agroforestry wastes provide the required nutrition for mushrooms development, and it is an important aspect of mushroom production in a green economy context (Rühl & Kües, 2007).

Figure 2. Steps for production of majority mushroom species used in world market



Source: Nguyen (2019).

In an analysis of the costs involved in every step of mushroom production, Celik and Peker (2009) detailed the significant influence of substrate preparation step in final cost for producers. The authors pointed that the cost of raw material acquisition for substrate preparation is almost 50% of variable costs of a mushroom production, approximately 5 x the temporary labor costs, the second major variable cost. These authors also detailed that variable costs are approximately 87% of the total costs in a mushroom production.

Thus, substrate preparation step represents almost a half of the final cost in a mushroom production. In Brazil, it is not different since the mushroom producers also deal with the low quality and the excessive cost of raw materials for substrate preparation which have significant impact in final cost (Vargas, 2011).

An opportunity described recently by various authors for cost reduction of substrate for mushroom production is the integration of this industry with other agri-food industries. There are some interesting results in Brazil in this area, an example is the use of by-products of bioethanol industries like straw, bagasse, and vinasse (Siqueira *et al*., 2015). This integration already exists in EUA, Canada and some European countries and considering the volume of by-products of bioethanol industries in Brazil, which is one of the major producers of this fuel, it could be an excellent opportunity of integration.

Other opportunity is the maize industry since Brazil is one of the major producers of this culture in the world and projections indicate an expansion of this market in the future. According with recent research made by FIESP (2020) Brazil is the third major producer of maize in world and Tooge (2019) reveals that negotiations are in charge to open the China market for Brazilian product. Thus, the volume of wastes derived from maize production that its already high will become even higher. According with Hanafi *et al.* (2018) cob, straw and sawdust, by-products of maize production, can be used as substrate for shimeji development production, reducing dramatically the mushroom production cost. On the other hand, the spent mushroom substrate (SMS) derived from shimeji production can be applied for production of various plants species, like maize. It is possible because recent research indicates that SMS can be considered a biofertilizer, since it contributes to increase the soil quality, reduces the pollutants uptake by plants, and provides Plant Growth Promoting Microbes (PGRM) that increases the plant development (Othman *et al.*, 2020).

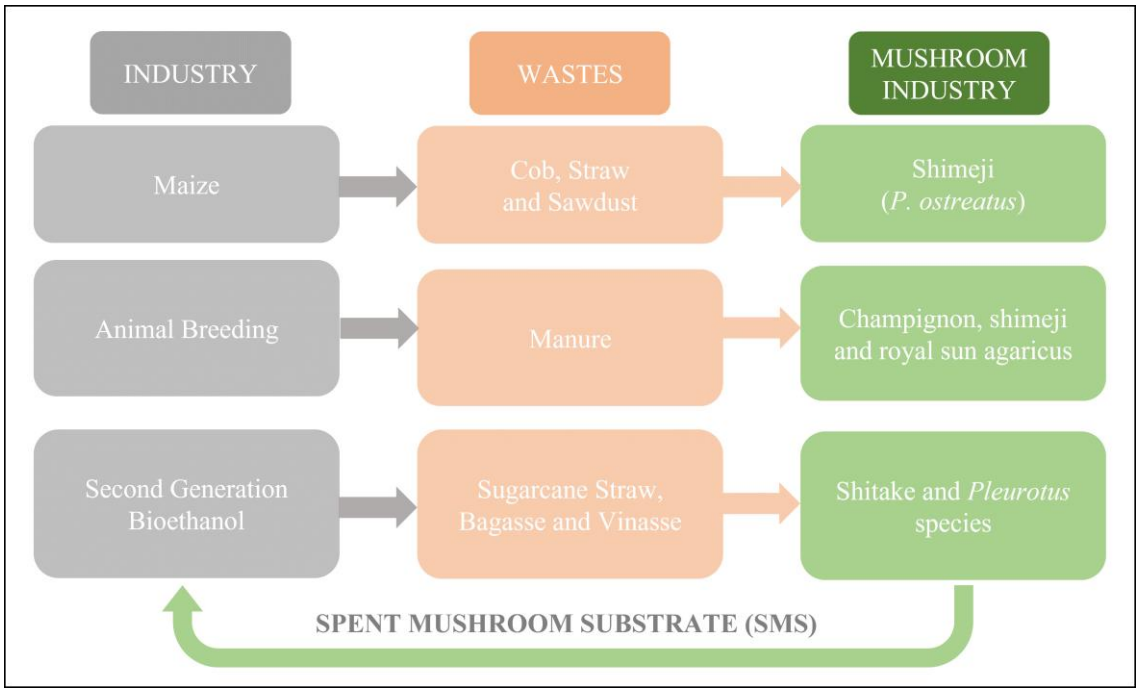
The manure produced in animal breeding is also an opportunity for substrate preparations via composting that can be utilized for shimeji, champignon and royal sun agaricus development (Vargas, 2011). Thus, the agri-food industries of Brazil could be an important source of substrate for mushroom production reducing dramatically the final cost of its production and, consequently, increasing the competitiveness with Chinese mushrooms. As detailed by Siqueira *et al.* (2015) SMS could be also utilized in bioethanol production, due to enzymes present in SMS composition that facilitates the process of sugar degradation. Other experiences for SMS application are being made as described by Machado (2019) that showed the use of shimeji SMS showed satisfactory results as substrate for the development of tomato (*Solanum lycopersicum*) plants.

In fact, even more recent publications extended the range of SMS applications. **Figure 3** provides a summary of some SMS uses and the integration of mushroom industry with other industries in a circular model considering the Brazil's industrial profile. Considering the types of industrial activities in Brazil and the main mushroom types produced the integration possibilities must be explored aiming a higher benefit/cost and the increase of competitiveness when compared to imported mushrooms.

As detailed by Kuzma & Sehnem (2021) in the study of circular economy there is a crescent demand for data in this field in modern societies. Thus, the knowledge about the potential uses of SMS can be valuable for cost reduction in industrial activities associated with

less negative impacts to the ecosystems. The use of green activity-based costing could help in future research to reveal the SMS potential in different industries (Mashkoor *et al*., 2023).

Figure 3. Spent mushroom substrate (SMS) origins and applications considering the main Brazil's industrial activities



Source: Hanafi *et al.* (2018); Siqueira *et al.* (2015); Vargas (2011).

CONCLUSIONS

The world mushroom consumption is a $63 billion market largely because of edible mushrooms, which are produced mainly by China. However, the high demand by "*In natura*" mushrooms in the last years cannot be attended by China at Brazilian market and it can be an important niche market for national producers. Defined as functional food, mushrooms production can represent an important market opportunity for Brazil because of the growing demand by "*In natura*" mushrooms in world and the highly positive forecast of the world mushroom market in the next years. However, the cost involved in mushroom production is high for Brazilian producers and it is in large part derived from substrate acquisition. An alternative for the reduction of mushroom production cost is the integration of mushroom industry with other industry. It is highly possibly using agri-food industrial wastes for mushroom production and the return of SMS derived of its production to these agri-food industries. This integration can be a way to promote a cost reduction in the Brazilian mushroom production and, thus, causing an increase of its competitiveness in this market.

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