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# CHAMUÇAS COM SUBPRODUTOS DE COGUMELO SHIITAKE: CARACTERIZAÇÃO FÍSICA E QUÍMICA

# SAMOSAS WITH SHIITAKE MUSHROOM BYPRODUCTS: CHEMICAL AND PHYSICAL CHARACTERIZATION

# SAMOSAS CON SUBPRODUTOS DE HONGO SHIITAKE: CARACTERIZACIÓN QUÍMICA Y FÍSICA

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## RESUMO

**Introdução:** O cogumelo shiitake é o segundo cogumelo comestível mais popular em todo o mundo. Assim, devido à crescente procura por cogumelos shiitake e consequente aumento de produção, uma quantidade significativa de subprodutos é gerada que pode ser encarada como resíduo.
**Objetivos:** O objetivo deste trabalho foi desenvolver novos alimentos de valor acrescentado, incorporando o cogumelo shiitake, como meio de utilizar matérias primas que não cumprem os padrões para comercialização.
**Métodos:** Foram desenvolvidos novos produtos alimentícios, nomeadamente chamuças, e para isso foi produzido um recheio a partir de uma receita original, e os produtos finais foram analisados quanto à sua composição química, cor, textura e atributos sensoriais.
**Resultados:** Os resultados mostraram que as chamuças com cogumelo shiitake possuíam composição química equilibrada, com proteínas e minerais, mas também com alguma gordura. A cor apresentou-se variável entre as amostras, embora em média ambos os lados das chamuças fossem praticamente iguais. A textura revelou-se macia, com baixa mastigabilidade, resiliência e coesividade moderadas e alta elasticidade. O painel sensorial apreciou o produto, atribuindo uma pontuação elevada (cerca de 4, numa escala de 1 a 5). Finalmente, algumas correlações significativas foram encontradas entre algumas avaliações sensoriais e correspondentes medições instrumentais.
**Conclusões:** Este estudo mostrou que podem ser produzidos novos produtos alimentícios de valor acrescentado a partir de materiais derivados da produção de cogumelos shiitake, que de outra forma teriam de ser descartados como resíduos agrícolas.

**Palavras-chave:** aproveitamento de subprodutos, composição química, cor, teste de compressão, teste de perfuração, propriedades de textura, propriedades sensoriais, resíduo de shiitaki, chamuças de shiitaki

## ABSTRACT

**Introduction:** Shiitake mushroom is the second most popular edible mushroom worldwide. Due to the increasing demand for shiitake mushrooms and consequent production increase, a significant amount of by-products is generated that could be considered as waste materials.
**Objectives:** The aim of this work was to develop new valued foods incorporating shiitake mushroom, as a means to use the products that do not comply with standards for commercialization.
**Methods**: New food products were developed, namely samosas, and for that a filling was produced from an original recipe, and the final products were analysed for their chemical composition, colour, texture and sensorial attributes.
**Results:** The results showed that the shiitake samosas had a balanced chemical composition, with protein and minerals, but also with some fat. The colour varied between samples, although on average both sides of the samosas were of practically equal. The texture was soft, with low chewiness, moderate resilience and cohesiveness and high springiness. The sensory panel appreciated the product by attributing a high score (about 4, on a scale from 1 to 5). Finally, some significant correlations were found between some specific sensorial evaluations and instrumental measurements.
**Conclusions:** This study indicated that new valued food products can be produced from materials derived from shiitake mushroom production, that otherwise would have to be discarded as agricultural residues.

**Keywords:** by-products valorisation, chemical composition, colour, compression test, puncture test, textural properties, sensory properties, shiitake by products, new shiitaki samosas

## RESUMEN

**Introducción:** El hongo Shiitake es el segundo hongo comestible más popular en todo el mundo. Por lo tanto, debido a la creciente demanda de hongos shiitake y el consiguiente aumento de la producción, se genera una cantidad significativa de subproductos que podrían considerarse materiales de desecho.
**Objetivos:** El objetivo de este trabajo fue desarrollar nuevos alimentos valiosos que incorporen el hongo shiitake, como un medio para utilizar los productos que no cumplen con los estándares para la comercialización.
**Métodos:** Se desarrollaron nuevos productos alimenticios, a saber, samosas, y para ello se produjo un relleno a partir de una receta original, y los productos finales se analizaron por su composición química, color, textura y atributos sensoriales.
**Resultados:** Los resultados mostraron que el shiitake samosas tenía una composición química equilibrada, con proteínas y minerales, pero también con algo de grasa. El color variaba entre las muestras, aunque en promedio ambos lados de las samosas eran prácticamente iguales. La textura era suave, con poca masticabilidad, resistencia moderada y cohesión y alta elasticidad. El panel sensorial apreció el producto al atribuir una puntuación alta (aproximadamente 4, en una escala de 1 a 5). Finalmente, se encontraron algunas correlaciones significativas entre algunas evaluaciones sensoriales específicas y mediciones instrumentales.

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**Conclusiones:** Este estudio indicó que los nuevos productos alimenticios valiosos se producirán a partir de materiales derivados de la producción de hongos shiitake, que de lo contrario deberían descartarse como residuos agrícolas.

**Palabras clave:** aproveitamento de subprodutos, composición química, color, prueba de compresión, prueba de punción, propiedades texturales e sensoriales, subprodutos de shiitaki, samosas de shiitaki

## INTRODUCTION

Shiitake mushroom (*Lentinula edodes*) has long been used as a vegetable in human diet and also as pharmaceutical in many countries around the world (Jiang, Luo, & Ying, 2015). Shiitake mushroom appears as the second most popular edible mushroom worldwide, after white mushroom (*Agaricus bisporus*), corresponding to about 25% of the worldwide mushroom production (Bisen, Baghel, Sanodiya, Thakur, & Prasad, 2010; Jiang, Wang, Xu, Jahangir, & Ying, 2010; Royse, 2014).
Shiitake mushroom comprises two distinct parts: the cap (the main body) and the stipe. While the cap is typically used for human consumption, the stipe is usually discarded because of its tough texture (Yu et al., 2010). Nevertheless, the value of the stipe has been identified as important, both in terms of nutritional value and also regarding the high levels of bioactive compounds (like phenolic compounds) as compared to the cap (Zhang, Chen, Zhang, Ma, & Xu, 2013).
Fresh shiitake mushrooms present a brown colour, closed caps and firm texture, being easily cropped and masticated. However, when stored their properties change, their colour darkens, caps tend to open thus exposing gills, the stipes elongate and the texture becomes rougher. In particular, the texture of shiitake mushrooms is much frequently the first of several quality attributes evaluated by consumers, being for that reason of exceptional importance for product acceptance (Jiang et al., 2010).
Past and recent studies have shown that shiitake mushrooms have an extraordinary nutritional value and contain many bioactive compounds, including polysaccharides, antioxidants, dietary fibre, ergosterol, vitamins (B1, B2 and C), folates, niacin and dietary minerals (Jiang et al., 2015; Mattila, Suonpää, & Piironen, 2000; Reis, Martins, Barros, & Ferreira, 2012; Zhang et al., 2013).
Shiitake, as other mushrooms in general, are highly perishable merchandises and therefore start deteriorating straightaway after harvest (Jiang et al., 2010).
Due to the gradually increasing quantity of shiitake mushrooms consumption, a significant amount of their stipes (by-products) considered as waste materials, is produced every day from mushroom farms and processors. Nevertheless, this ample accessible resource may potentiate possibilities and opportunities for the food industry to increase economic profitability by adequate usage and processing of these mushroom by-products. Therefore, investigations to produce new added-value products from these discarded by-products are needed. Furthermore, farmers are faced frequently with the fact that some products do not comply with standards for selling, for example due to small size or irregular shape, although they are perfectly good in terms of taste, composition and nutritional value. Hence, providing alternative ways to take advantage of these materials that otherwise would be waste are highly appreciated (Martins & Ferreira, 2017; Mirabella, Castellani, & Sala, 2014; Van Ba et al., 2017).
The objective of this work was to develop new valued foods incorporating shiitake mushroom, as a way to utilize the products that do not comply with standards for commercialization (in terms of size or shape), thus avoiding waste, and creating added value for farmers. With that purpose, a samosas' recipe was developed, with the incorporation of shiitaki by-products. The obtained product was evaluated regarding the chemical composition, physical properties (such as colour and texture) and sensorial attributes. Up to our knowledge similar studies are missing in the literature, including the characterization of other samosas, and thus a lack of scientific information is found on this particular topic.

## 1. METHODS

### 1.1 Cultivation of the shiitake mushrooms

The mushrooms were produced in a farm (*Ementa Sustentável*), located in the city of Viseu, Portugal, and the production systems that is carried out is exclusively organic, that is, no chemical products on any type are used in the culture.
The shiitake mushrooms are produced in wood logs, which are carved with wooden pegs previously inoculated with the fungi in laboratories. The production takes place inside a greenhouse, with rows of logs arranged in a "U" system. There are about 5 rows of logs (Figure 1). There is a vertical watering system downstream, so that water falls on the wooden logs. Moisture and temperature are controlled in several points inside the greenhouse.

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**Figure 1 -** Disposition of the wooden logs inside the greenhouse (left) and mushroom production (right).

The ideal moment for the harvest is when the mushroom presents the "hat" open between 50% and 80% of its development. To collect the mushrooms, the base must be firmly hold and then a slight twist must follow, without damaging the bark of the logs and avoiding to leave in them residues of mushrooms. After their collection, they are separated according to their size (small, medium or large) and also according to their opening (open or closed). The mushrooms harvested should be stored immediately under refrigeration or freezing. At *Ementa Sustentável*, they are placed in the refrigerator (at a temperature between 4 and 8 ºC) until they are sold or, in the case of the open mushrooms, until they are processed (they can be dehydrated or used for the preparation of derived food products). However, mushrooms may not and should not be refrigerated for longer than one week. For periods longer than those, mushrooms must be dehydrated. Open mushrooms are more susceptible to faster and more intense degradation and that is the reason why they are usually used for processing.

**1.2 Preparation of the samosas**

For the preparation of the filling, the mushrooms were washed and cut, and they were inspected to see if any part would have to be rejected for being at improper state for usage (Figure 2). The mushrooms were then dried with kitchen absorbent paper and placed overnight to drain. Each batch consisted of 10 samosas of 140 g each (60 g filling plus 80 g dough). For the preparation of 1 kg samosas, 8 g of garlic were peeled and chopped, and then fried in a pan with olive oil. After that, 320 g of mushrooms were added to cook along with the garlic. As soon as the mushrooms released all their water, 110 g of chopped onions were added to the mixture, which was seasoned with salt (2.4 g), pepper (0.8 g), chilli (0.4 g), curry (4.0 g), coriander (3.2 g) and parsley (3.2 g). The mixture was left to cook for about 10 minutes.

For the preparation of the dough 480 g of flour, 12 g of salt were weighed and 80 mL water was added to start kneading. While kneading, the necessary water was added until the dough was cleared from the workbench surface. Afterwards, the dough was well worked and finally was ready to cut and shape.

The dough was stretched with a kitchen roll until a thin, rectangular layer was obtained, which was taken to the oven for only 2 minutes at 180 ºC. Then the dough was removed from the oven and allowed to cool slightly at room temperature. Rectangular strips, about 20 cm wide, were cut from the dough, worked on a non-adherent working surface. For each strip, 60 g of filling were placed at one end of the stripe and the dough was folded to obtain the shape of the samosas, which were finally fried in vegetable oil at 160 ºC for 5 minutes (Figure 2).

**Figure 2 -** Shiitake mushrooms used for the filling (top) and fried samosas (bottom).

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### 1.3 Chemical analyses
For chemical analyses, six units were selected from three lots of samosas for representativeness. The samples were ground for standardization and for each determination a mass was taken from this homogeneous mixture. All determinations were made following standard procedures (AOAC, 2000) and analyses were made in triplicates. The chemical determinations included moisture, ash, fat, fibre, protein and salt (chlorine).

### 1.4 Evaluation of colour
Colour was measured using a colorimeter Konica Minolta CR-400, and the Cartesian Coordinates were measured: L*, a* and b* (CIELab colour space). Lightness is represented by L* and varies from 0 (black), to 100 (white). Coordinates a* and b* can have negative or positive values, so that when a* is negative it represents greenness and when positive is redness, while b* represents blueness and yellowness, respectively for negative and positive values (Gonçalves, Guiné, Gonçalves, & Costa, 2017). Colour measurements were made on 10 samosas, three replicates on each side.

### 1.5 Evaluation of texture
For analysis of the textural parameters, a texturometer TA-XT2 (Stable Microsystems) was used. The texture profile analysis (TPA) was used, consisting of two compression cycles with a 5 s interval between them. For compression a flat probe with 75 mm in diameter (P/75) was used. The operating conditions of the test were: 30 kg force load cell, pre-test, test and post-test rates equal to 0.5 mm/s, distance 3 mm and trigger force 0.1 N. The textural properties: hardness, resilience, springiness, cohesiveness and chewiness were calculated after equations (1) to (5) (see Figure 3) (Correia et al., 2017):

$$\text{Hardness (N)} = F_1 \quad (1)$$
$$\text{Resilience (\%)} = (A_5/A_4) \times 100 \quad (2)$$
$$\text{Springiness (\%)} = (T_2/T_1) \times 100 \quad (3)$$
$$\text{Cohesiveness (\%)} = (A_2/A_1) \times 100 \quad (4)$$
$$\text{Chewiness (N)} = F_1 \times (T_2/T_1) \times (A_2/A_1) \quad (5)$$

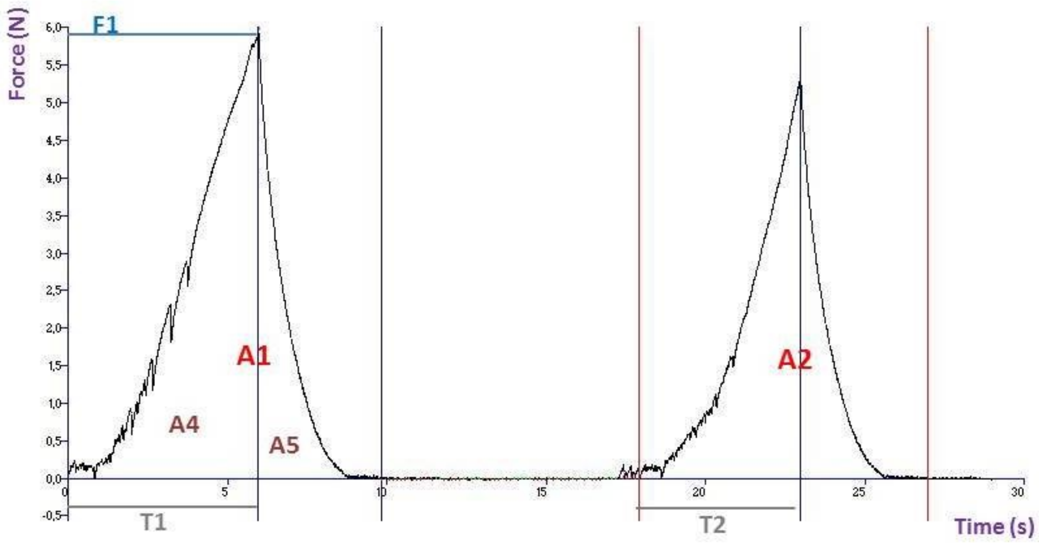


**Figure 3 -** Example of a texture profile analysis obtained for the samosas.

For all textural evaluations 10 samosas were used and the results were processed using Exponent software TEE from Stable Micro Systems

### 1.6 Sensorial evaluation
The sensorial analysis involved tests for descriptive sensory profile, and was executed by a non-trained panel of 25 judges, but whose members had previous experience in sensory evaluations. The samples were placed whole over an odour-free, white plastic dish. Deionised water and unsalted crackers were provided for palate rising in-between the samples. Samples were served at room temperature and the tasting room was kept at 22ºC ± 2 ºC. The sensory attributes were evaluated for the dough and for the filling. In each case the taster was asked separately to evaluate the dough only and later the filling only. For the dough the parameters evaluated were: appearance (colour, uniformity), aroma (pleasantness), taste (salt, pleasantness), texture (hardness, crunchiness, thickness) and global appreciation. For the filling the evaluated parameters were: appearance (colour,

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uniformity), aroma (pleasantness), taste (salt, curry, mushroom, pleasantness), texture (moist, creaminess, uniformity) and global appreciation. Finally, an overall assessment of the whole samosa was undertaken. All attributes were scored on a scale varying from 1 (the lowest intensity of the attribute) to 5 (the highest intensity).

### 1.7 Statistical analysis

All data were expressed as mean values and standard deviation. Also the coefficient of variance was calculated (CV (%) = standard deviation/mean value*100) and possible outliers were also investigated. The Pearson correlation coefficients were used to analyse the possible associations and interdependence between properties. For absolute value of r = 0 there is no correlation, for r ∈]0.0, 0.2[ the correlation is very weak, for r ∈[0.2, 0.4[ the correlation is weak, for r ∈[0.4, 0.6[ the correlation is moderate, for r ∈[0.6, 0.8[ the correlation is strong, for r ∈[0.8, 1.0[ the correlation is very strong, for r = 1 the correlation is perfect (Maroco, 2012; Pestana & Gageiro, 2014).
For all statistical analyses was used the software SPSS version 24 (IBM, Inc.) and the level of significance considered was 5% ($p < 0.05$).

## 2. RESULTS AND DISCUSSION

### 2.1 Chemical components

Table 1 shows the mean values and corresponding statistical parameters for the chemical components evaluated in the shiitake samosas. The moisture content was 37.23%, being this mostly due to the filling, since the dough after frying becomes quite dehydrated. The protein content was 5.63%, which is probably caused by the presence of shiitake mushroom which has 2.69% protein (Y. Tian, Zhao, Huang, Zeng, & Zheng, 2016). Associated to the absence of fat and cholesterol, several mushrooms, and also shiitake, are considered privileged sources of protein. There are many proteins present in mushrooms which have demonstrated biological activities, from which are just mentioned lectins, fungal immunomodulatory proteins (FIP), ribosome inactivating proteins (RIP), ribonucleases and laccases. These have demonstrated to have natural antitumor, antiviral, antimicrobial, antioxidative and immunomodulatory activities (Xu, Yan, Chen, & Zhang, 2011).
The relatively high fat content would be expected, having in mind that the samosas are fried in vegetable oil, thus absorbing part of it during processing. This kinetics of oil absorption is influenced by several factors, such as the oil quality, frying temperature, frying time, possible usage of pre-treatments and the composition of the food being fried. However, presently there is a growing interest in minimizing this problem, by reducing the fat absorption through modification of frying techniques and monitoring of frying temperature and oil degradation (Kurek, Ščetar, & Galić, 2017). Therefore it is recommended to follow these trends when frying the shiitake samosas.
The salt content of the shiitake samosas was found to be 0.25%, and this is very important because salt has been related with many health problems, particularly regarding heart health and kidney functioning. Dietary salt restriction is essential in the management of heart failure, since high salt intake critically increases blood pressure (DiNicolantonio, Chatterjee, & O'Keefe, 2016; Mishra, Ingole, & Jain, 2017; Yano, 2018). Also, dietary salt restriction has been found useful for management of autosomal dominant polycystic kidney disease, being therefore highly recommended a reduction in its ingestion (Torres et al., 2017).

**Table 1 -** Results of the chemical analyses made to the shiitake samosas.

| Property (unit) | Mean value | Standard deviation | Coefficient of variance |
|---|---|---|---|
| Moisture (%) | 37.23 | 0.30 | 0.79 |
| Ash (%) | 2.55 | 0.19 | 7.29 |
| Fat (%) | 12.79 | 1.60 | 12.60 |
| Fibre (%) | 2.01 | 0.21 | 10.35 |
| Protein (%) | 5.63 | 0.22 | 3.01 |
| Salt (%) | 0.25 | 0.04 | 2.58 |

### 2.2 Colour

Figure 4 presents the results of the evaluation of colour coordinates in the samosas, taken as individual samples and separating the measurements made on both sides, to investigate the degree of uniformity of the products. The results indicate that for all colour coordinates (L*, a* and b*) there was a degree of variability both from one samosa to another samosa and also from one side to the other side of the same samosa. This is natural, since the frying operation induces important changes in colour, which may not be equal, not even for the products submerged in the same oil (Santos, Molina-Garcia, Cunha, & Casal, 2018; J. Tian et al., 2017).

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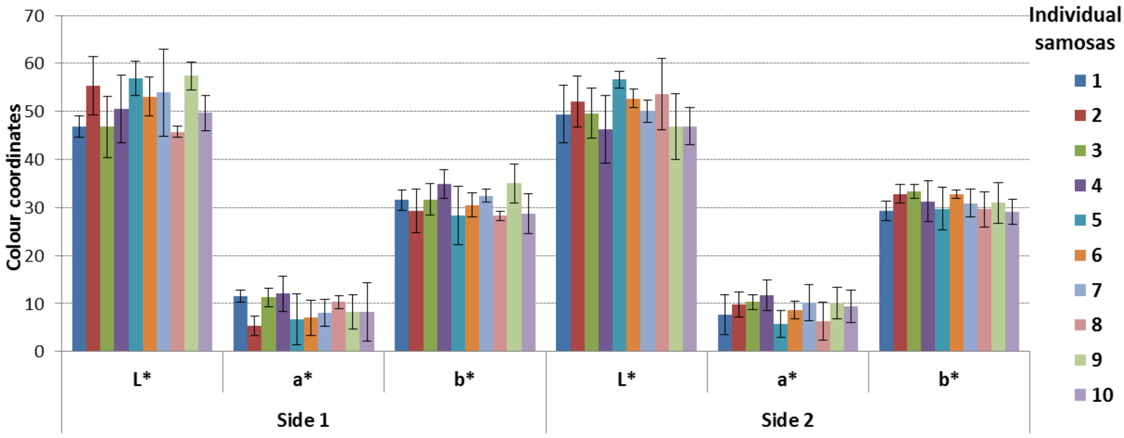


**Figure 4 -** Colour coordinates of the shiitake samosas separated by sample.

Figure 5 presents the values of the colour coordinates calculated as averages of the 10 samples analysed. Interestingly, despite the slight variability observed for the samples, the average values are quite similar for both sides of the shiitake samosas: 51.62 and 50.41 for lightness, 8.89 and 8.99 for redness and 31.06 and 30.99 for yellowness, on sides 1 and 2 respectively. The samples are light, with L* of about 50, with a slight tone of red (positive but low values of a*), and with an intense yellow coloration (positive high values of b*).

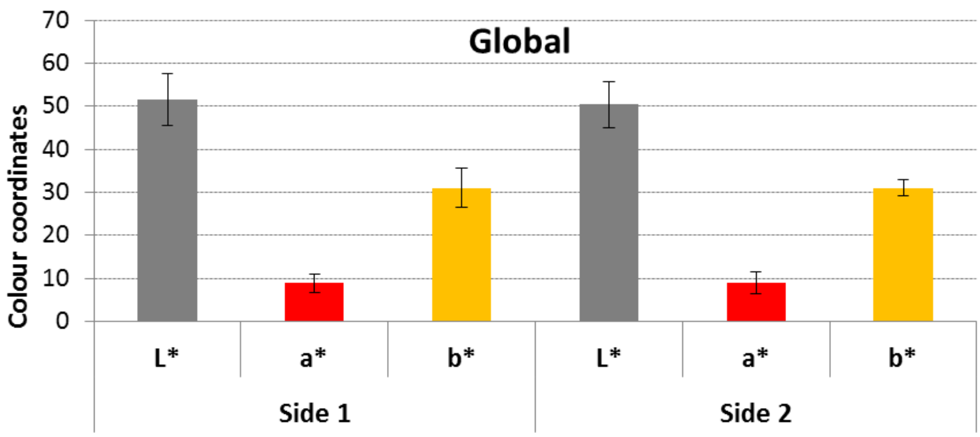


**Figure 5 -** Colour coordinates of the samosas determined as average of the 10 shiitake samosas.

### 2.3 Textural properties

Figure 6 presents the textural properties obtained by TPA, expressed as average of 10 measurements in different shiitake samosas. Hardness represents the force necessary to compress a food between the teeth or between the tongue and the palate. Chewiness measures the energy required to disintegrate a food to a state suitable to swallow. Springiness is associated with the ability to recover shape after compression, being equal to the rate at which the product returns to the initial point after removal of the deforming force. Resilience is the energy used when applying a force to a material without occurring rupture, with or without any residual strain, and corresponds to an instant springiness. Cohesiveness represents the internal forces inside the food that stop the sample from disintegrating (Cruz, Guiné, & Gonçalves, 2015; R. P. F. Guiné, Henriques, & Barroca, 2014; Raquel P. F. Guiné, Almeida, Correia, & Gonçalves, 2015).

The results in Figure 6 show that the shiitake samosas were quite soft, with hardness of only 4.28 N, and the value of chewiness was also low (2.55 N). This results on one hand from the fact that the dough was prepared intentionally as a soft dough, and on the other from the fact that the textural properties were not measured right immediately after frying, as the dough tended to lose some of its crunchiness and become softer, as observed also for example for French fries (Rahimi, Adewale, Ngadi, Agyare, & Koehler, 2017; Thussu & Datta, 2012). Resilience and cohesiveness presented relatively similar values, 38.72% and 33.84%, respectively, indicating that the strength of the internal bonds of the samples were not high. On the other hand, the value of springiness was high (85.24%), thus indicating that the products under study were relatively elastic.

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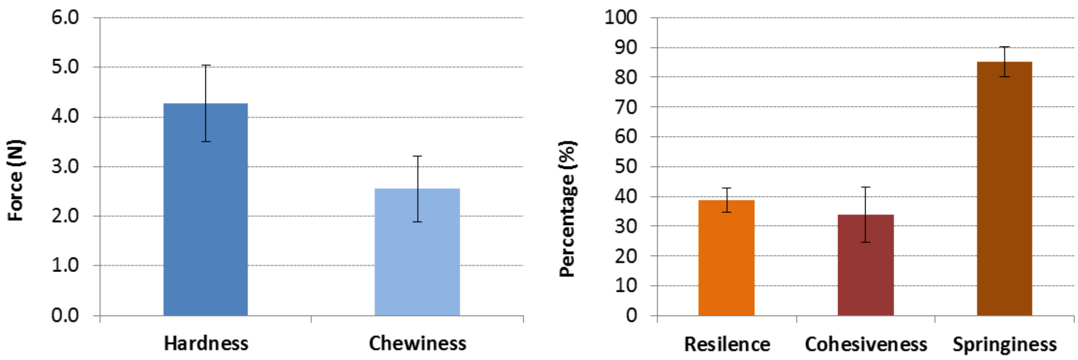


**Figure 6.** Textural properties of the samosas determined as average of TPAs performed on 10 shiitake samosas.

### 2.4 Sensorial characteristics

Figure 7 presents the sensorial characteristics of the dough and filling used to produce the shiitake samosas. The attribute least scored was salt, both in the dough and in the filling, indicating that the amount of salt added was low, as recommended. The dough was high scored for colour, uniformity, aroma, pleasantness of taste, crunchiness and thickness, with mean scores over 3.5, on a scale from 1 to 5. Hence, as a general result the dough was appreciated by the members of the sensorial panel. Regarding the filling, the highest score was obtained for intensity of curry (4.15), as it would be expected given the type of product and the seasonings used in the formula. Also, the filling got high scores (over 3.5) for attributes like colour, aroma, pleasantness of taste and uniformity of texture, thus indicating that the panellists appreciated the filling.

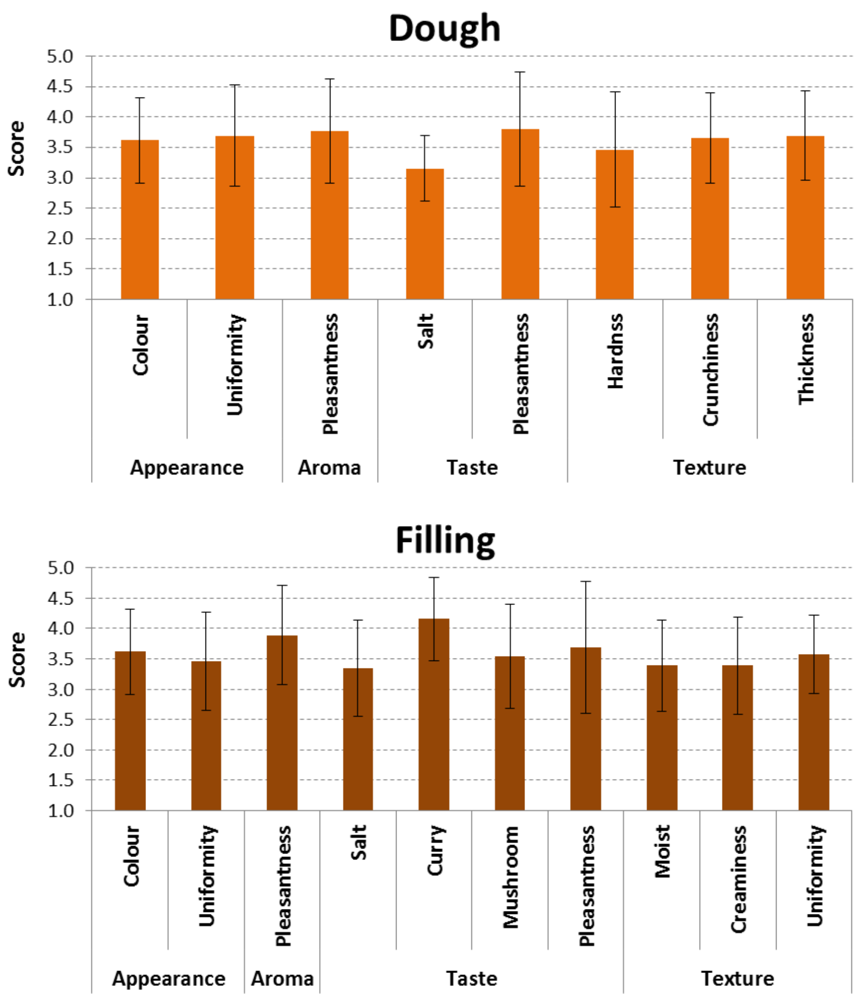


**Figure 7 -** Sensorial characteristics of the dough (top) and filling (bottom) of the shiitake samosas.

The average score for overall assessment of the whole samosas (Figure 8) was 4.04 points (percentage of answers: scores 1 and 2 = 0%, score 3 = 23%, score 4 = 50%, score 5 = 27%), which reveals that the shiitake samosas were highly appreciated by the panellists, with an average score relatively close to the highest value of the scale considered for evaluation (from 1 to 5 points). Interestingly, the global appreciation of the dough was on average 3.88 points while that of the filling was 3.85 points, both lower when compared with the value obtained for the whole samosa. This means that the combination of the two parts results in a more appreciated product than both parts separately.

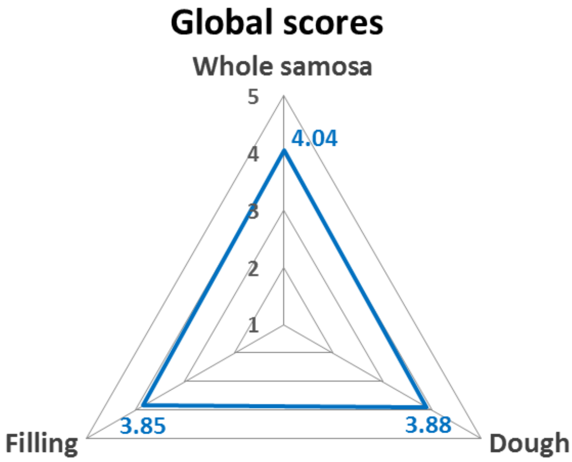


**Figure 8 -** Global scores for the dough, filling and whole shiitake samosas.

### 2.5 Correlations

Table 2 shows the Pearson correlations between some of the variables studied, i.e., the textural properties and some sensorial attributes that might related to them. There are a few strong correlations at 1% significance level (sensory perception of hardness with instrumental measurement of hardness: r = 0.675; sensory perception of creaminess with instrumental springiness: r = 0.757; sensory perception of crunchiness with instrumental springiness: r = -0.632, in this case the correlation is negative). Other strong correlations were found significant at 5% level (sensorial hardness with instrumental chewiness: r = 0.617; sensorial thickness with instrumental hardness: r = 0.674). In all other cases the correlations were pour or moderate, which might be related to the fact that the panel used for sensorial analysis was not a trained panel for this type of product specifically. Furthermore, the transposition of results obtained through perception measured on a hedonic scale into measurement made with precision instruments might also explain some lack of correlation in certain properties.

**Table 2 -** Pearson correlation coefficients between some sensorial characteristics and the textural properties.

| | | Textural Properties | | | | |
|---|---|---|---|---|---|---|
| | | Hardness | Chewiness | Resilience | Cohesiveness | Springiness |
| Sensorial Characteristics | Hardness (Dough) | 0.675** | 0.617* | 0.597 | 0.356* | -0.276 |
| | Crunchiness (Dough) | -0.313 | -0.114 | -0.213 | -0.469* | -0.632** |
| | Thickness (Dough) | 0.674* | 0.497* | 0.368 | 0.507* | -0.169 |
| | Mushroom (Filling) | 0.303 | 0.278* | -0.089 | 0.458* | 0.505* |
| | Moisture (Filling) | -0.310* | -0.281 | 0.137 | -0.338* | 0.121 |
| | Creaminess (Filling) | 0.374 | 0.211 | 0.396 | -0.468* | 0.757** |

## CONCLUSIONS

The present work allowed concluding that the chemical composition of the shiitake samosas was balanced, being rich in protein and minerals, although with some non-negligible fat content. As for colour of the samples, it varied from sample to sample, although on average the values of the colour coordinates were very similar on both sides of the samosas. Regarding texture the

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shiitake samosas were found relatively soft and with low chewiness, with moderate resilience and cohesiveness and high springiness. Sensorial evaluation allowed concluding that both the dough and the filling as well as the whole shiitake samosas were highly scored, indicating that they were relatively appreciated by the panellists. Finally, some significant correlations were found between some sensorial evaluations and instrumental measurements, like for example the feeling of creaminess with springiness or the harness perceived by the panellists and that measured by the texturometer.

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