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Original scientific paper

Estimation of fat content in fermented sausages by means of Computer Vision System (CVS)

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A b s t r a c t: The aim of this study was to investigate the possibility of computer vision system (CVS) application in fat content estimation for different types of fermented sausages. Four different types of local fermented sausages with different fat contents were studied: Njeguška, Kulen, Pirotska and tea sausage. Results obtained for CVS-estimated fat content were compared to the results of traditional chemical analysis. Relative errors of fat content estimation in Njeguška, Kulen, Pirotska and tea sausage were 1.47%, 0.46%, 20.84% and 11.19%, respectively. Results of t-test showed a significant (p<0.01) difference between mean fat contents obtained by CVS and chemical analysis in the case of Pirotska sausage. On the other hand, there was no significant (p<0.01) difference between mean fat contents obtained by the two methods for the rest of the analysed sausages. The results indicate CVS has potential for application in the analysis of fat content of fermented sausages.
Keywords: *computer vision, fat content, fat estimation, fermented sausages, dry sausages.*

Introduction

Dry fermented sausages are an important part of European consumer diet (*Simunovic et al.*, 2020). Average annual consumption of dry and processed meat in Serbia in 2017 was 14.41 kg per capita (*Statistical Office of the Republic of Serbia*, 2018). Generally, fermented sausages are produced using two main ingredients, meat and pork back fat. Characteristics of the final product depend on the type and quality of the ingredients, processing conditions and microbial ecology (*Prado et al.*, 2019). However, fermented sausages are acidified, either by undergoing relatively extensive fermentation processes as a result of the activity of lactic acid bacteria or by addition of acidifiers like glucono-delta-lactone. During fermentation, lactic acid bacteria generate lactic acid which decreases the sausage pH and plays an important role in flavour formation in the final product. In addition, use of different spices like paprika, which is used in production of Chorizo and Kulen, contributes to the development of specific flavour characteristics of sausages (*Salgado et al.*, 2005; *Ikonić et al.*, 2013). Geographic origin, tradition and natural resources have influenced the development of the variety of these meat products around the world.

In recent years, there has been increasing consumption of low-fat products, which led to a number of attempts to reduce fat content in fermented sausages (*Olivares et al.*, 2010; *Stajic et al.*, 2018; *Pintado and Cofrades*, 2020). In most cases, addition of fat replacers like olive and linseed oil failed to meet consumer demands in terms of colour, texture and flavour (*Stajic et al*., 2018; *Pintado and Cofrades*, 2020). Fats are important from the physiological point of view because they contain a number of vitamins and essential fatty acids and are an important source of energy. In addition, fat contributes to the different sensory characteristics of flavour, juiciness, appearance and hardness. According to *Olivares et al.* (2010), low-fat fermented sausages were less appreciated by consumers compared to those with higher fat content. On the other hand, fat content is an important economics parameter for dry sausages. Commercial fermented sausages usually

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contain around 32% fat after stuffing and around 40–50% in the end product (*Wirth*, 1988). A higher fat content in sausage formulation reduces the production price due to the lower price of back fat compared to meat. As a consequence of high fat content, the quality of these products can be deteriorated, so fat content is also considered as a quality parameter.

According to Serbian Regulation (*Official Gazette RS*, 2019), the free fat content in fermented sausages should be determined using SRPS ISO 1444:1998, which is identical to ISO 1444:1996 (*ISO*, 1996; *SRPS ISO*, 1998). Apart from being time-consuming and laborious, the method involves the use of organic solvents which are not considered environmentally friendly. More precisely, the method is based on the Soxhlet extraction using n-hexane or petroleum ether. In recent years, an increased interest in the field of green chemistry has been reported (*Doble and Kruthiventi*, 2007). Development of automated, accurate and precise methods that do not require use of organic solvents would be of interest not only for producers and laboratories but for the environment.

In recent years, there has been a number of studies regarding implementation of computer vision system (CVS) into different food industries. In the studies of *Milovanović et al.* (2020) and *Tomasevic et al*. (2019), colour measurements of fresh meat and various processed meats by means of CVS were more accurate and precise than measurements obtained by the traditional method. This was even more obvious for bi-coloured products like fermented sausages. The main advantage of CVS is the possibility of image processing using a number of available software products on the market that provide many different options for the image analysis. A recent study by *Djekic et al.* (2021) demonstrated the possibility of calculating the particle size distribution of boluses obtained from pork ham samples processed by three different culinary methods. Furthermore, the intramuscular fat content of *M. longissimus dorsi* was estimated using a computer vision based method with an accuracy of 82.63% (*Du et al.*, 2008). These results were in accordance with those reported by *Faucitano et al.* (2005), who determined a strong correlation between estimated fat content by CVS and fat content obtained by chemical analysis of pork. The authors identified a knowledge gap in CVS application in the analysis of the fat content of dry sausages. Therefore, the aim of this study was to investigate the possibility of CVS application in fat content estimation for different types of local fermented sausages.

Materials and Methods

Fermented sausages

Four types of fermented sausages with different fat contents were obtained from local manufacturers. Two of the sausages were commercial fermented sausages (Kulen and tea sausage), while the other two were produced by traditional means (Njeguška and Pirot ironed sausage). All the sausages were vacuum packed and transferred to the laboratory in refrigerated boxes.

Determination of fat content

Collagen casings of Kulen and tea sausage were removed prior to homogenisation in a bowl chopper (Blixer 2, Robot Coupe, France). On the other hand, Njeguška and Pirot ironed sausage were homogenised with their edible natural casings. Free fat content was determined according to SRPS ISO 1444:1998 (*SRPS ISO*, 1998). Briefly, homogenised sausages were dried according to ISO 1442:1997 (*ISO,* 1997) until they reached constant mass. Afterwards, dried homogenates were subjected to Soxhlet extraction using n-hexane. Extracted components in n-hexane were dried and measured, based on which, the free fat contents were calculated.

CVS analysis

The CVS system consisted of one closed cubical wooden box illuminated with four fluorescent lamps (Philips, Eindhoven, the Netherlands). The interior of the box was coated with black opaque photographic cloth, as described by *Tomašević et al*. (2019b). Sausages were cut into 10 mm thick slices and placed on a white board. The board with a sausage slice was placed on the bottom of the box and photographed with a Sony Alpha DSLR-A200 digital camera, as previously explained by *Tomašević et al*. (2019b). The procedure was repeated for each type of analysed sausage. Images were imported into Adobe Photoshop 2020 (Adobe Inc., San Jose, CA, USA), where the white background colour was replaced with green in order to avoid interferences during colour segmentation. Processed images were converted into PNG format and imported into ImageJ (National Institutes of Health, Version 1.45 K) software in order to perform colour segmentation. For each picture containing a sausage slice, three clusters were identified using Color Segmentation plugin. The first cluster represented the colour of fatty tissue, the second corresponded to the colour of meat, while the third

Figure 1. Results of colour segmentation analysis of Kulen sausage: original image (left), background colour adjustments (middle) and colour segmentation (right).

referred to the green background colour (Figure 1). The third cluster was only used to calculate percentages for the first two clusters.

Statistical analysis

Mean values and standard deviations were obtained using SPSS package (SPSS 23.0, Chicago, IL, USA). In order to compare results obtained by the two methods, the paired-sample T-test was used, with statistical significance being set at $p<0.01$. MS Excel (Microsoft, Redmond, WA, USA) was used to calculate the percentages of meat and fat areas on the face of the sausage slices.

Results and Discussion

The fat content of Njeguška sausage was the highest among all the analysed sausages. The results are in accordance with the study of *Simunović et al*. (2020), who found high fat content in Njeguška sausage. The estimated fat content of Njeguška sausage by means of CVS was 43.66% while the chemically determined fat content was 44.31% (Table 1). The measurement values obtained by the two methods used were extremely close. The relative error for fat content estimation of Njeguška sausage by CVS was 1.47%. Despite the relatively low relative error of the CVS method, results showed a higher standard deviation (SD) compared to traditional chemical analysis, which indicates that the data were more spread out from the mean. The reasons for this could be in the coarsely ground meat batter and uneven distribution of meat and fat in the sausage. Njeguška is a traditional dry sausage with pieces having a unique cross section, usually formed by mincing the meat and fat through a plate with 13 mm diameter holes (*Simunović et al*. 2020). In addition, production of dry sausages by traditional means usually involves mixing of the batter by hand, which could be the reason for uneven distribution of meat and fat. However, there was no significant ($p<0.01$) difference between mean values obtained by CVS and traditional chemical analysis.

On the other hand, the mean fat content determined by the two methods significantly ($p<0.01$) differed in the case of Pirot ironed sausage. According to *Simunović et al.* (2019), the sausage is traditionally made from a combination of beef, chevon and mutton which are trimmed off visible fat.

Table 1. Estimated fat content (mean±standard deviation) in different types of fermented sausages and comparison of fat contents from CVS and traditional chemical analyses

Type of fermented sausage	Estimated fat content by CVS (%)	Chemically determined fat content (%)	Result comparison (%)
Njeguška	43.66±4.14[a]	44.31±0.19[a]	98.53
Kulen	32.75±4.21[a]	32.60±1.42[a]	100.46
Tea	36.16±1.47[a]	32.52±0.21[a]	111.19
Pirotska	11.25±0.71[a]	9.31±0.04[b]	120.84

Legend: [a, b] Values in the same row followed by different letters are significantly different ($p<0.01$)

However, the final product always contains a low level of fat, partially as a result of the presence of intramuscular fat in meat cuts. The relative error of fat content estimation by CVS in Pirot ironed sausage was 20.84% and was the highest among all analysed sausages. During ripening of Pirot ironed sausage, the natural casing (beef small intestine) into which the meat batter is stuffed becomes covered with white moulds. As mentioned above, a white background colour can interfere with fat colour during colour segmentation. This resulted in the white sausage casing clustering with the fatty tissue, which consequently affected segmentation results. However, the edible casing is considered as part of the product and is homogenised with the sausage prior to chemical analyses. From this, it can be concluded the proposed CVS method needs to be modified in the case of sausages covered with white moulds.

The chemically determined fat content of tea sausage analysed in this study was 32.60%, which is lower than that reported by *Dzinić et al.* (2015). *Dzinić et al.* (2015) analysed tea sausages from six different manufacturers and found that free fat content in analysed sausages varied from 36.43% to 59.80%. The estimated mean fat content of tea sausage by means of CVS was numerically higher than that obtained by chemical analysis (Table 1). However, t-test results showed no significant ($p<0.01$) difference between mean fat contents obtained by the two methods. The relative error of the estimated fat content by means of CVS was 11.19%. This high relative error could indicate that the proposed CVS method has difficulties in colour segmentation of finely chopped fermented sausages. In addition, in the study of *Du et al.* (2008) it was showed that CVS has difficulties in distinguishing between fat and connective tissue due to their similar colours, which could be one of the reasons for our high relative error. Tea sausage is characterised by finely comminuted meat batter that is formed by mincing meat through a plate with 4 mm diameter holes and comminution in a bowl cutter. Fine comminution of meat batter allows producers to use meat with a high content of connective tissue. According to *Official Gazette RS* (2019), the collagen content in total meat proteins must not exceed 15%. However, *Dzinić et al*. (2016) reported the collagen content in total meat proteins of six tea sausages obtained from different producers ranged from 10.09% to 18.11%. The high content of connective tissue could be one of the reasons for the lower accuracy of CVS in estimating the fat content of tea sausage.

In the present study, the chemically determined free fat content of Kulen was 32.60%, which was higher than that reported by *Parunović et al*. (2013) but lower than those reported by *Ikonić et al*. (2010) and *Branković Lazic et al.* (2019). The relative error of the estimated fat content by means of CVS was 0.46%, which was the lowest error among all the sausages analysed. In addition, there was no significant ($p<0.01$) difference between mean fat contents obtained by the two applied methods, which indicates CVS could potentially be applied in the analysis of Kulen's fat content. However, the standard deviation of the CVS method was higher than that of chemical analysis. Because of that, it is important to include an appropriately high number of slices in CVS analysis of Kulen fat content.

The proposed method is based on cluster identification depending on defined R (red), G (green), B (blue) values. Each pixel of an image displays colours by the combination of red, green and blue. Image segmentation is performed by assigning specific RGB colour to a cluster. K-means or hidden Markov model algorithms are then used to calculate the percentage of each defined cluster in the image. More precisely, algorithms process every pixel of an image and match each with just one of the clusters, i.e., with the most closely approximate defined colour. As a result of this process, every pixel of the image is assigned to one of the clusters, and the results are expressed as a percentage for each cluster in the image. Because of this, it is important that background colour of the image is different from the colour of the sample (*Du et al.*, 2008). However, in cases where the white background colour interferes with the colour of fatty tissue, it is advisable to change background colour to produce a clear boundary between background and the sausage slice.

Conclusion

In this study, a novel method for estimation of fat content in fermented sausages was proposed. Fat content estimation showed high accuracy in the case of Kulen, Njeguška and tea sausage. However, high SDs for CVS-estimated fat content indicate that the number of tested sausage slices should be as high as possible in order to obtain more accurate results. Application of the proposed method would reduce time and cost of the analysis compared to traditional chemical measurements. In addition, the method is environmentally friendly because it does not involve use of organic solvents. The proposed CVS method showed difficulties in distinguishing between the colour of fatty tissue and connective tissue.

Procena sadržaja masti u fermentisanim kobasicama primenom kompjuterskog vizuelnog sistema

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A p s t r a k t: Cilj ovog rada bio je da se ispita mogućnost primene kompjuterskog vizuelnog sistema u proceni sadržaja masti u različitim tipovima fermentisanih kobasica. Četiri različita tipa fermentisanih kobasica su izabrana: Njeguška, Kulen, Pirotska i Čajna kobasica. Rezultati dobijeni primenom kompjuterskog vizuelnog sistema upoređeni su sa rezultatima sadržaja masti dobijenih pomoću konvencionalne hemijske analize. Relativne greške kompjuterskog vizuelnog sistema u proceni sadržaja masti za Njegušku, Kulen, Pirotsku i Čajnu kobasicu bile su 1.47%, 0.46%, 20.84% i 11.19%, respektivno. Rezultati t-testa pokazali su statistički značajnu ($p<0.01$) razliku između srednjih vrednosti dobijenih pomoću kompjuterskog vizuelnog sistema i hemijske analize u slučaju Pirotske kobasice. Sa druge strane, rezultati nisu pokazali značajne razlike između srednjih vrednosti dobijenih primenom dve metode u slučaju ostalih ispitivanih kobasica. Dobijeni rezultati ukazuju na mogućnost primene komjuterskog vizuelnog sitema u analizi sadržaja masti fermentisanih kobasica.

Ključne reči: *kompjuterski vizuelni sistem, sadržaj masti, fermentisane kobasice, suve kobasice.*

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