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Estimation of fat cover of bovine carcasses by means of computer vision system (CVS)

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Abstract. The aims of this study were to obtain percentages of meat and fat cover for SEUROP classification system reference images using a computer vision system (CVS) and to calculate classification intervals which could be used in the future for construction of cheap and easy to use classification devices for small slaughterhouses. Lowest percentages of fat cover were found for the first class marked as “low” (the lowest fat content) and they gradually increased to the last class marked as “very high” (the highest fat content). Based on the obtained results, decision making intervals were proposed. In the present study, classification only refers to classification of adult bovine animals based on fat cover.

1. Introduction

In 2013, global beef consumption remained at the same level (around 9.5 kg/capita) as it was in 1961 [1]. During the same time, the world population increased from around 3.3 billion to 7.3 billion with annual population growth rate of 1.2 % (from 2003 to 2013) [2]. As a result, world production of beef increased during 1961-2019 from 28.76 million tons to 72.60 million tons [1]. However, average beef consumption per capita in Serbia in 2017 was 5.15 kg while the number of cattle reduced from 1949 to 2017 from 1,946,000 to 899,000, respectively [3, 4]. For improvement of cattle numbers in Serbia, it is necessary to implement agro-economic policy and strengthen farmers' associations [5, 6]. In addition, it is necessary for beef producers to follow new trends on the market and try to differentiate their products on the basis of geographical origin and specific nutritional characteristics [7]. According to Grunnert et al. [8], competitiveness on developed food markets is associated with the ability of companies to develop new differentiated products that reveal differences in consumer preferences and move away from price-based competition.

In 1981 in Europe, Regulation No 1208/81 was brought into force. The regulation refers to classification of carcasses of adult bovine animals, widely known as the SEUROP system [9]. A few months later, in order to ensure uniform classification, it was necessary to define carcass conformation and fat classes more precisely [10]. Briefly, regulations refer to classification of both, carcass



conformation and fat cover. For the classification of fat cover, the five following classes were defined: 1 – low (L) (“no fat within the thoracic cavity”), 2 – slight (S) (“within the thoracic cavity the muscle is clearly visible between the ribs”), 3 – average (A) (“within the thoracic cavity the muscle is still visible between the ribs”), 4 – high (H) (“the seams of fat on the round are prominent, the muscle between the ribs may be infiltrated with fat”) and 5 – very high (VH) (“the round is almost completely covered with fat, so that the seams of fat are no longer clearly visible, within the thoracic cavity the muscle between the ribs is infiltrated with fat”) [10].

In the beginning, classification of beef carcasses was optional, but in 1995 it became mandatory [5]. At first, the regulation was used for the purpose of monitoring market prices, while today, it is used to form the price of cattle sold to the slaughterhouse [5]. However, it was difficult to establish a unique means of classification between different slaughterhouses in Europe because the classification was done manually by the food operators. Although visual classification has long been used by the industry, it is a method of subjective nature depending on the experience and intuition of the operator. Furthermore, this means of classification required greater manual labor, and consequently, it increased the production cost. Many years later, in developed countries, automated classification systems have been developed and applied by the industry. On the other hand, in developing countries, the SEUROP classification system is not being used, mostly because it requires manual labor and trained operators. In addition, automated systems are, in most cases, too expensive for small slaughterhouses.

In recent years, there have been numerous studies on the application of computer vision systems (CVS) in the analysis of different food products [11-17]. Milovanovic et al. [18] measured the color of twenty-seven different milks and milk products by means of CVS and found that the method was more reliable and accurate compared to traditional devices for color measurement. Nyalala et al. [19] reported a number of studies which investigated the possibility of weight and volume estimation of poultry and eggs using CVS-based methods. In addition, Pietro Cavallo et al. [20] used a computer vision-based method for quality evaluation of table grapes, which showed accuracy of 92% and 100% in classifying the cultivars Victoria and Italia, respectively. Apart from being more accurate, computer vision-based methods are usually non-destructive, which is one of the reasons for their increasing popularity.

The aims of this study were to obtain percentages of meat and fat cover of SEUROP classification system reference images using CVS and to calculate classification intervals that could be used in the future for constructing cheap and easy to use classification devices for small slaughterhouses. In the present study, classification only refers to classification of adult bovine animals based on fat cover.

2. Materials and Methods

2.1. Carcase images

The study was carried out on reference images for classification of carcasses of adult bovine animals (see <https://op.europa.eu/en/publication-detail/-/publication/248996ec-f513-4852-a2a5-6fd307692b0a>). The images were downloaded and imported into Adobe Photoshop 2020 (Adobe Inc., San Jose, CA, USA), where they were cropped and converted into PNG format. Reference images for each class are provided for both the inner carcass part (in the thoracic cavity) and the outer carcass part (outside of the carcass) (Figure 1).



Figure 1. Reference images for classification of carcasses of adult bovine animals

2.2. CVS analysis

As the background of the reference images is black and significantly differs from color of meat and fatty tissue, it was not necessary to change it. However, the images were imported into Adobe Photoshop 2020 (Adobe Inc., San Jose, CA, USA) software in which the color of the entire image was changed to black and white in the way that there was a clear color difference between meat and fat parts (Figure 2). This procedure was repeated for each of the reference images. The images were then imported into ImageJ (National Institutes of Health, Version 1.45 K) software which was used for the purpose of color segmentation, wherein three clusters were defined. The first cluster represented the color of meat, the second indicated the color of fatty tissue while the third referred to the background color.



Figure 2. Computer vision analysis of bovine carcasses: original image (left), black and white adjustments (middle) and color segmentation (right).

2.3. Statistical analysis

For the calculation of percentages of each cluster, percentages of fat cover of bovine carcasses and proposed intervals for decision making, MS Excel (Microsoft, Redmond, WA, USA) was used.

3. Results and Discussion

Table 1 shows results of estimated fat cover of reference images for classification of adult bovine animals obtained by means of CVS. Lowest fat content was found for the first class i.e., carcass images with the lowest fat content in the thoracic cavity and on the outside of the carcass. Estimated fat content in both images, in the thoracic cavity and outside of the carcass, gradually increased from the first class marked as “low” to the last class marked as “very high”. The highest difference in estimated fat cover between the following groups for images of the outside of carcass was observed between the first (“low”) and the second class (“slight”), which showed fat content of 47.51% and 56.07%, respectively. On the other hand, the difference in fat cover of these two classes in images of the inner carcass part was 1.21%. Based on the percentages of fat cover obtained for each reference image, decision making intervals were proposed (Table 2). However, the main challenge in developing a mathematical model was classification of those carcasses for which results of fat cover for inner and outer parts of carcass were not in accordance. It was observed that during CVS analysis of images representing inner carcass parts, the method has difficulties distinguishing between the color of bones and fatty tissue. This was especially obvious for the rib region, which was classified in the fat cluster in all of the analyzed images. For this reason, images of the outside of carcass should be of greater importance when it comes to classification. In the future, it is necessary to determine the importance of factors which would take into account the color similarity of bones and fatty tissue in order to facilitate decision making.

Table 1. Percentages (%) of meat and fat of bovine carcasses in the thoracic cavity and outside of the carcass of reference images obtained by CVS

		Categories				
		L	S	A	H	VH
Outside of the carcass	Meat	52.49	43.93	40.23	38.97	36.42
	Fat	47.51	56.07	59.77	61.03	63.57
In the thoracic cavity	Meat	42.66	41.45	39.38	33.83	30.50
	Fat	57.36	58.54	60.62	66.17	69.50

As is the case with pork fatty tissue and pork, the tallow price is a few times lower than the beef price. Heifers naturally contain more tallow than bulls, which is the reason for their lower price. On the other hand, bulls are characterized by a high meat content, which is why they are more appreciated on the market. This indicates the economic importance of fat cover classification and why producers should improve meat yield. Implementation of fat cover classification would encourage producers to improve diets and breeding conditions in order to increase the meat content in their cattle, which would have positive economic effects for both producers and slaughterhouses. There are many studies focusing on development of different diets and breeding conditions for cattle in order to improve yield, growth performance and marbling [21, 22]. One of the important quality characteristics of beef that directly affects consumer purchase decisions is marbling [23]. Marbling is defined as “intramuscular fat and dispersion of fat within the lean meat” [24]. Liu et al. [24] investigated the correlation between European conformation and fat scores and marbling scores obtained by sensory panel. However, SEUROP fat scores only showed weak correlation with marbling ($P < 0.001$; $r = 0.45$), while conformation scores were not related with marbling.

Table 2. Proposed intervals in percentages (%) for different categories of carcass fat cover

		Categories				
		L	S	A	H	VH
Outside of the carcass	Meat	>48.21	48.21-42.07	42.08-39.59	39.60-37.66	<37.67
	Fat	<51.79	51.79-57.91	57.92-60.39	60.40-62.30	>62.30
In the thoracic cavity	Meat	>42.05	42.05-40.40	40.41-36.59	36.60-32.16	<32.16
	Fat	<57.95	57.95-59.57	59.58-63.38	63.39-67.83	>67.83

4. Conclusion

The study showed the possibility of CVS application in fat cover estimation of reference images for classification of bovine carcasses based on fat content. However, the limitation of this study was in the lack of a reference method for carcass classification based on which results could be compared. In addition, CVS showed difficulties in distinguishing between color of fatty tissue and color of bones and connective tissue. In the future, there is a need for development of a mathematical model that could be incorporated in classification software.

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