Quality Assessment of Bologna Sausages Using Machine Vision

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Keywords:

digital image processing,
cluster analysis,
salami, cold cuts, Lyoner

Abstract. Non-destructive methods, such as digital image processing, play important role in the quality assessment since all members of the supply chain can check any product delivered. A simple, low cost and portable machine vision system was used in the presented study to estimate quantity of ingredients of Bologna sausages (also known as Lyoner). Five types of tested sliced sausages differ in ingredients: pork sausage with cheese, cucumber, pepper, mushroom and turkey sausage with cheese. Samples were collected from retail store. Ten slices were measured on both sides, therefore 20 images were acquired by sample groups. Pictures were preprocessed using linear or quadratic normalization depending on the contrast. Segmentation was performed using manually selected training samples and cluster analysis. Based on the surface area of segmented clusters and density data, ratio of ingredients were estimated in m/m % and results were compared to the label. The error of estimation was in the range of 0.22 – 5.49 m/m % where the smallest error was observed for ingredient of cheese and the largest for cucumber. Coefficient of variation was similar for all products. The proposed method needs further improvement but already obtained promising results.

INTRODUCTION

Meat is essential component of human nutrition. Depending on its source and quality, the typical protein and fat content vary in wide range, in 15-23% and 2-37%, respectively (Szabó, 2006). Meat protein is important due to its essential amino acids. Fat content contributes to the texture and sensory value of meat (Corbin et al., 2015; Ventanas et al., 2010). Especially in beef, the fat structure called marbling is investigated. Marbling affects significantly palatability, tenderness, juiciness and flavour of beef. The tissue of meat is also rich in minerals, such as Na, K, Ca, Mg, Fe and Zn. The vitamin content primarily means vitamin B, small amount of vitamin A and C can be found as well (Szabó, 2006). The meat consumption in Hungary is balanced between pork and poultry. The annual consumption per capita in 2015 was 27.5 kg of pork and 28.8 kg of poultry (KSH, 2017). Among meat products, Bologna type cooked sausages are very popular. Food industry continuously develops products for better nutritional value, longer consumption period, impressive appearance and better taste. Low fat Bologna sausage can be produced using pork skin and green banana flour gel as fat replacement. It was observed that product color and texture did not change significantly with 60% portion of replacement gel (Agostinho dos Santos Alves et al., 2016). The gel also improved cooking loss and emulsion stability, while sensory quality was acceptable above 60% as well. Jongberg et al. (2013) found plant extracts helpful in prevention of oxidative protein modifications, except thiols. Green tea and rosemary extracts were added to raw materials of sausages. Additionally, lipid oxidation was inhibited by extracts and protein carbonyl formation changed positively. New additives used in sausages change their physical attributes, such as colour and density. This effect has to be considered in their optical recognition and quantity estimation.

Application of machine vision systems in food industry first focused on perishable produces using colour, surface pattern and shape features (Baranyai & Szepes, 2002). Quality assessment and monitoring of raw materials was found to be successful. Image processing technology is today part of the quality monitoring in several areas from fruits and vegetables such as strawberry, cereals and potato, to complex foods such as seafood, bakery products and pizza (Sun, 2008). These methods mainly rely on segmentation of macroscopic compounds or estimation using derived indices. The interaction of light and biological tissue was observed to change during ripening of horticultural produces and also depend on chemical compounds and physical state. The pattern of laser light migration in tissue was able to distinguish certain commercial grades of kiwifruit (Baranyai & Zude, 2008) and follow changes of products during postharvest and processing (Baranyai, 2011). The cutting-edge technology of hyperspectral imaging is able to estimate compounds according to their spectral response and provide information on spatial distribution. Moisture loss and drying pattern was observed on carrot slices using hyperspectral imaging system (Firtha, 2009; Kaszab et al., 2008). Regarding macroscopic components, fat and meat ratio and their structure, called marbling, was evaluated with this method (Felföldi et al., 2013). Provided that compounds are clearly visible and algorithms are able to recognize them by colour or pattern, there is no need for chemical information extracted from spectra. Colour imaging might be suitable for such food products.

The objective of the presented work was to estimate macroscopic ingredients of cold cuts using economic and portable vision system. The application of low cost vision system and colour image processing may help install quality check points rapidly.

MATERIALS AND METHODS

Five different types of Bologna sausages were acquired from retail store (Fig.1). One sausage was made of turkey meat, others were made of pork meat. Ten slices were used from each sample and both sides were captured by vision system. Cold cuts were placed on transparent plastic sheet over blue paper background. The blue background colour was selected to facilitate segmentation.

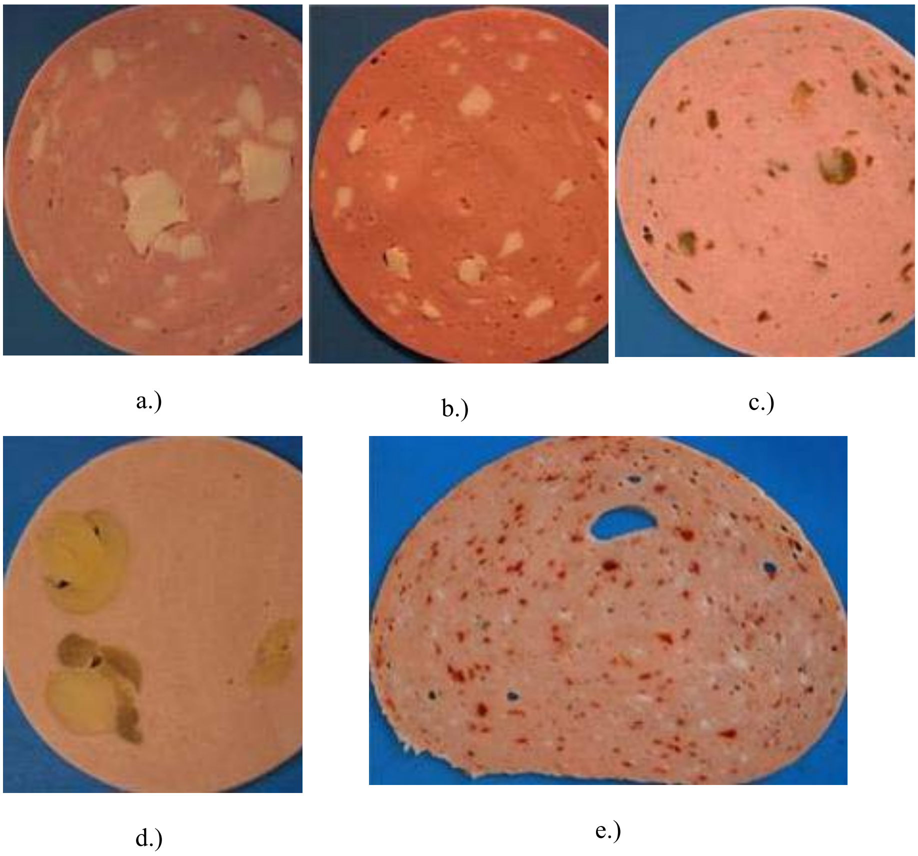

Figure 1
Bologna sausage samples
a: Parizer with cheese, b: Turkey Parizer with cheese, c: Parizer with cucumber,
d: Parizer with mushroom, e: Meat bread

A Samsung NX300 camera with 20.3 Mpx (megapixel) CMOS sensor was placed above samples. Auto exposure mode was selected in order to maximize colour contrast on the surface. The resolution was adjusted to 0.136 mm/px. Saved images were preprocessed with normalization according to the following equations:

$$C_{n,i} = \frac{C_i}{\sum_{j \in R,G,B} C_j} \quad (1)$$

$$C_{n,i} = \frac{C_i^2}{\sum_{j \in R,G,B} C_j^2} \quad (2)$$

where C_i and C_j mean intensity of colour channel i and j respectively, $C_{n,i}$ means normalized intensity of colour channel *i*. Equation 1 presents calculation for linear normalization, while Eq.2 shows quadratic computation. Linear method highlights dominant colour but quadratic formula also increases colour contrast. The type of normalization was decided according to the observed contrast on the cold cut surface and the same computation method was used for the same sausage. Dynamic k-means clustering was applied in segmentation. The segmentation process resulted in grayscale image where compounds were identified by intensity level. Due to the uniform thickness of cold cuts, proportion of surface areas represents volume ratio as well. Density is required to transform volumetric information to mass ratio, what is comparable with official label (EU No. 1169/2011). Density of the meat pulp may vary a lot depending on recipe and quality of ingredients. Meat pulp density was estimated with the following simplified equation:

$$\rho_p = \frac{m_m + m_f}{\frac{m_m}{\rho_m} + \frac{m_f}{\rho_f}} \qquad (3)$$

where ρ_p, ρ_m and ρ_f means density of pulp, meat and fat, respectively; m_m and m_f are mass of meat and fat, respectively.

Self developed software was used for normalization and segmentation. The software was built using C++. Statistical analysis of obtained data was performed using IBM SPSS Statistics (IBM Corp., USA). Descriptive statistical attributes were calculated for samples and differences were evaluated according to their significance.

RESULTS AND DISCUSSION

Machine vision system was able to identify visible ingredients of sausages (Fig.1). Diffuse illumination and separating plastic sheet between slices and background paper removed disturbing shadows and decreased misclassification error.

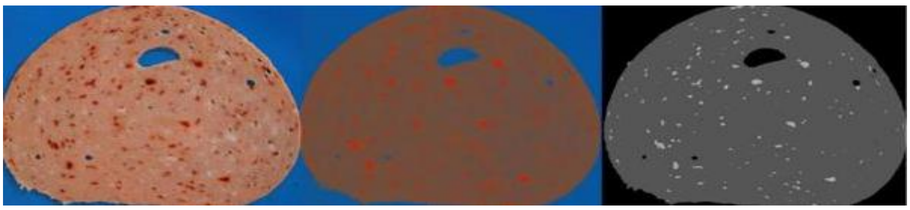

Figure 1
Recognition of sausage ingredients
(left to right: colour image, normalized image, segmentation result)

Correct density data is essential for reliable calculation. After investigation of related literature and consultation with experts of the Department of Refrigeration and Livestock Products' Technology of the Faculty of Food Science at Szent István University, density was estimated as 0.9 g/cm^3 for meat and 0.8 g/cm^3 for fat. Pulp density did vary in the range of 0.86 – 0.9 g/cm^3. Due to the high variability of cheese products, density of selected cheese block, the type is most likely to be used in technology, was measured manually before experiments. It was found to be 1.1 g/cm^3.

Descriptive statistical parameters of samples (minimum, 25% quantile, meadian, mean, 75% quantile, maximum, standard deviation) are reported in the following table (Table 1). Multimodal distribution was observed in case of sample "Parizer with cheese". Slight deformation from normal distribution was observed for sample "Parizer with cucumber". Asymmetric distribution with more frequent low values was observed in case of samples "Parizer with mushroom" and "Turkey parizer with cheese". Due to the differences in frequency distribution compared to normal, the nonparametric one sample Kolmogorov-Smirnov test was also applied in order to confirm one sample t-test results.

Table 1: Descriptive statistical values of samples

Sample	Min.	25% Q	Median	Mean	75% Q	Max.	Std.dev.
Parizer with cheese	9.51	11.43	14.16	13.78	16.28	16.99	2.78
Turkey parizer with cheese	4.21	5.63	6.54	6.49	7.45	8.57	1.23
Parizer with cucumber	4.34	6.00	6.73	6.51	6.95	8.90	0.99
Parizer with mushroom	13.62	16.30	19.26	19.23	21.26	25.32	3.28
Meat bread (with paprika)	1.48	1.72	2.05	2.06	2.39	2.95	0.42

Calculated mean values were compared to the official information of the label. This reference value was provided by the manufacturer. The following table (Table 2) shows comparison results, where reported significance was calculated according to the one sample t-test ($p<0.05$). The best estimation was reached for pork parizer with cheese. Generally it was found that amount of cheese and mushroom was well predicted. Approximately 54% of reference value was calculated for cucumber. On the other hand, amount of paprika in pork meat bread was over estimated with additional 72%. All vegetables were calculated using the same density value accepted in the current practice of meat product processing. This density value fits well to mushroom, but resulted in large prediction error for others. Since recipe and processing technology are patented and protected by law, we cannot discuss them here in details. At this point it can be suggested to technology experts to revise simplified calculation and measure density of ingredients.

There seems to be contradiction in statistical results, since largest prediction error was reached for samples of lowest standard deviation. The coefficient of variation ranged 0.152 – 0.202, lowest for cucumber. These results together are likely to show that prediction works well for accurate initial information (density values, full list of ingredients with quantity). Best prediction was achieved with measured cheese density and worst with assumed cucumber density. Visual check of cucumber recognition confirmed segmentation accuracy, therefore its unexpectedly low value can be result of wrong density or too low amount of ingredients.

Table 2: Comparison of measured m/m% of ingredient with label information (reference)

Sample	Reference	Measured	Significance
Parizer with cheese	14	13.78	0.730
Turkey parizer with cheese	7	6.49	0.077
Parizer with cucumber	12	6.51	0.000*
Parizer with mushroom	20	19.23	0.331
Meat bread (with paprika)	1.2	2.06	0.000*

* $p<0.05$

CONCLUSIONS

Machine vision system built from low cost colour camera and simple diffuse illumination was used to capture images of Bologna sausages. Normalization of colour images was applied during preprocessing in order to enhance colour contrast of ingredients. This step allows vision system to work automatically and adapt itself to current conditions. Visible ingredients were successfully identified and mass ratio was computed (m/m %) similar to label information provided by manufacturer. Good prediction accuracy was achieved for three types (pork and turkey meat with cheese, pork meat with mushroom) and large error was observed for two (pork meat with cucumber and paprika). Results suggest to perform such estimation based on preliminary measurements of density. Prediction accuracy ranged 0.22 – 5.49 m/m% in the presented experiment. Although the pilot system can work well, further development is recommended to build a robust single box device. The introduced technique is promising and can be recommended for quality monitoring due to its rapid installation and easy management.

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