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Detecting And Quantifying Feather Meal By VIS-NIR Spectroscopy

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***Abstract*— The meat industry involves the slaughter of animals and the generation of end- and by-products. By-products represent environmental and economic problems for meat processors if they are not correctly treated. In Hungary, approximately 287 thousand tons of livestock (meat and slaughterhouse) waste, as well as nearly 45 tons of animal carcasses generated annually. The emerging poultry slaughterhouse trimmings and separate collection of blood is partially solved at the enterprise. 6 t/day of blood and other trimmings generated at the company, of which amount is expected to grow significantly due to the capacity expansion of broiler production. Thus in the frame of this project a corporation in Nyírbátor is planning a comprehensive investment program in which the produced slaughterhouse wastes will be connected selectively from each other and by-products, secondary raw materials can be produced. The aim of this study is investigating the possible determination of the chemical composition of feather meal by its optical properties, especially moisture content. The reflectance spectroscopy is a rapid, non-destructive, effective method that can be used for determining the composition of a number of agricultural and food products. Preliminary measurements were performed to evaluate the different products on the detection of the VIS NIR spectral range (400-1000 nm) by AvaSpec 2048 spectrometer. The results are evaluated by the ENVI 5.0. Inflection point of feather meal is determined by the software. The inflection point of feather meal is in range of 679-682 nm. As a result, we can determine that range of wavelenght, which is suitable to detect individual characteristics of feather meal. Analysing the samples it was concluded that inflection point of feathe meal is in range of 679-682 nm. The changes in the infrared range could be associated nutritional values of feather meal samples. Thus, using spectral investigation determining composition of feather meal could be quick and low energy method.**

Keywords—component; feather meal, VIS-NIR, spectroscopy

I. INTRODUCTION

The meat industry involves the slaughter of animals and the generation of end- and by-products. By-products represent environmental and economic problems for meat processors if they are not correctly treated. In Hungary, approximately 287 thousand tons of livestock (meat and slaughterhouse) waste, as well as nearly 45 tons of animal carcasses generated annually. The emerging poultry slaughterhouse trimmings and separate collection of blood is partially solved at the enterprise. 6 t/day of slaughterhouse waste generated at the company, of which amount is expected to grow significantly due to the capacity expansion of broiler production. Thus in the frame of this project a corporation in Nyírbátor is planning a comprehensive investment program in which the produced slaughterhouse waste will be connected selectively from each other and by-products, secondary raw materials can be produced. One of these materials is feather [1] [2].

The aim of this study is investigating the possible determination of the chemical composition of feather meal by its optical properties. The reflectance spectroscopy is a rapid, non-destructive, effective method that can be used for determining the composition of a number of agricultural and food products.

Considering general rules of waste management rate of utilization of animal waste is 80 %.The amount of sludge from the wastewater of food industry is annually 150 tousand tonnes. 66 % of sludge is generated in meat industry, 30 % in poultry industry and 2-3 % generated by ATEV (Animal Feed Production Company). It is necessary to sterilize and pre-treat animal by-products to pruduce different types of products. The most commonly used method is the semi-continuous dry method, also known as ATEV-method, which is adopted in Hungary by ATEV. Sterilization occurs at least 20 minutes at 130 °C [3].Variable amounts of waste to be expected according to species, recovery, health condition of the livestock and age groups.

Animal waste means livestock or poultry excreta or a mixture of exreta with feed, bedding, litter or other materials from an animal operation, which is an additional consequences of activity. We can group the types of animal waste by different aspects: original

place, dangerousness and physical-chemical charasteristics. One of the poultry by-products is feather, whose moisture content is between 50-70 %. The produced feather meal nowadays utilized as flower soil and fertilizer additives.

Spectroscopy is an attractive, fast method which recquires minimal sample preparation for examine of meat quality and animal by-products to which we applied AvaSpec 2048 spectrometer. The method spread in the last 30 years and has proven effective. Not only in the visible range studies have been made in the area, but the NIR technique has been used by many researchers for examine meat and meat products as well. We applied AvaSpec 2048 spectrometer.

Cozzolino and Murray [4] identified animal meat muscle by visible (VIS) and near infrared (NIR) technique. The examination is based on that in many cases high-quality meat products were replaced cheaper and lower quality meat products such as mechanically separated meat and offal.

Ben-Gera and Norris (1968) [5] have already been examined fat and moisture content in meat products using near technology. A special spectrophotometer prepared by the authors was used to measure the linear equations between composition and transmission which describes the moisture content in the range of 45 and 75 wt % with 1.4 wt % error and the fat content in the range of 5 and 35 wt % with 2.1 wt % error. It was found that the main source of error due to the fluctuation in thickness of the sample and a low signal/noise ratio by the high degree of absorption. Reflection measurements can reduce both of the errors.

Rosenthal (1973) [6] reported a methodology, where near infrared (NIR) reflectance technique was applied to determine the fat content of meat products. This technique was fast and non-destructive method.

Tena et al. (2014) [7] examined the differentiation of meat and bone meal from fishmeal by near-infrared spectroscopy. They have performed a sterilisation process of the meat and bone and fish meal at 133°C. During the sterilization, moisture and fat contents were removed from the material. Then, dried materials were milled. Statistical analyses were performed in three steps. As a first step, partial least squares discriminant analysis (PLS-DA) was used. The spectral investigation was from 1655 to 2500 nm region. The PLS-DA model was applied on 259 wavelengths. Based on the spectroscopy analysis, absorbance in the 1720 nm wavelength was higher for meat and bone meal than for fishmeal.

By a recently pusplished study the NIR-microscopy is one of the methods that is suitable for testing animal protein feed [8]. Previous studies have shown the potential of this technology using in detection of animal feed. However, these researches were based on spectral libraries which are not only apply for animal products and that makes slightly difficult to built database of these products. Therefore we need researches as widest as possible in this field. The measurements were made by FT-NIR spectrometer among others. The animal origin ingredients was recognized in animal mixed feed by this method.

Detection of moisture content, maturation and changes of pigment of apple is examined by spectroscopy as well [9][10][11][12][13]. Examined fruit production and evaluation of drought stress detection possibilities by spectral methods in an apple orchard [14][15].

An inflection point is defined as a point on a curve at which the sign of the concavity changes. Since the concavity can be reflected by the sign of the second derivative, an inflection point also means a point on a curve at which the second derivative changes sign. So the second derivative is helpful to judge an inflection point. A necessary condition for x to be an inflection point is the second derivative, $f''(x)$, is equal 0to zero if it exists. A sufficient condition requires $f''(x+\epsilon)$ and $f''(x-\epsilon)$ to have opposite signs in the neighborhood of x.Inflection point of feather meal is determined by the software [16]. For example in case of plant vegetation red edge inflection point, which is related to chlorophyll content [17][18].

II. MATERIALS AND METHODS

6 t/day of slaughterhouse waste generated at the company, of which amount is expected to grow significantly due to the capacity expansion of broiler production. One of the secondary materials is feather, which is 35 % of them (Figure 1.). During the research we develop a method to determine chemical composition of feather meal by its optical properties.

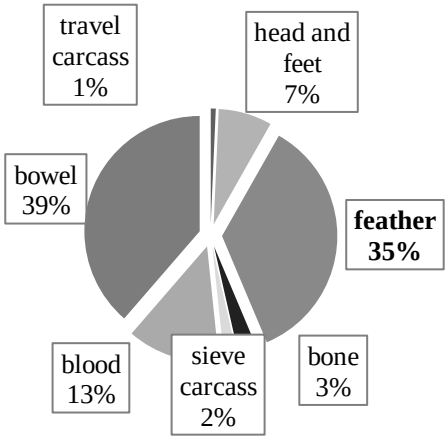

Fig 1. *Poultry by-products and waste from the examined*

The spectral detectability of feather meal were analyzed in laboratory conditions. The spectral profiles (reflectance) were measured by laboratory scale AvaSpec 2048 spectrometer at 400 – 1000 nm wavelength interval with 0.6 nm spectral resolution. The AvaSpec 2048 system consists of one spectrometer, AvaLight-HAL halogen light source which are joined by a fibre optic with 8 μm diameter. The halogen light source provides a constant emission of 400 – 1000 nm wavelength interval, which ensures a standard intensity of incoming energy in the whole range of measurement. However, laboratory

measurements is disturbed by lot of factors such as the changeable lighting conditions, neon lights, due to the wavelength specific emissions of fluorescent lamps. To ensure accurate measurements, a self-innovated, special sampling box were used to isolate samples in order to provide dark for measurements. The spectral profiles of the soil samples was measured at various moisture conditions.

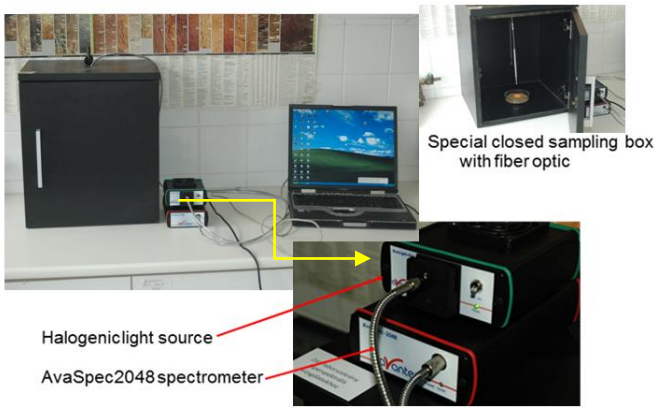

Fig 2. *AvaSpec 2048 system during measurement, and special sampling box*

Analysis of reflectance value of feather meal

The number of samples is 14, which was prepared to the spectral examination. After we calculated the average of spectras, we determine standard deviation as well (Figure 3.).

Spectral curve can be characterized by Equation (1) which is a third degree function:

$$y = 2 \cdot 10^{-5} \cdot x^2 + 0{,}0414 \cdot x + 3{,}1856 \qquad (1)$$

Searching the position of inflection point could be calculated by derivation of spectra. Representing the first derivative the maximum value will show position of the inflection point. Calculation was made by equation (2) by Tsai and Philpot (1998) [19]:

$$\frac{dy}{dx_i} = \frac{y_j - y_i}{x_j - x_i} \qquad (2)$$

where,

y: reflectance

x: wavelenght

In several studies second derivative of the spectra was used to analyzing the samples by equation (3):

$$\frac{d^2y}{dx^2} = \frac{y_k - 2 \cdot x_j + y_i}{(x_j - x_i)^2} \qquad (3)$$

where,

y: reflectance

x: wavelenght

The results are evaluated by the ENVI 5.0. Inflection point of feather meal is determined by the software. Algorithm, which is used by the softver calculate double derivate. Where the presage of second derivate change, theri is the position of the inflection point. This result will be transform to binarian code, 0=convex, 1=concave. Thus the curve clearly identify the inflection point.

III. RESULTS

By-products are examined generated during poultry processing by a high resolution spectrometer. The number of analyzed samples is 14. Generated reflectance values and standard deviation are represented in Figure 3. Reflectance value of protein meal samples typically increase with the wavelenght. It is observable in case of feather meal as well.

Individual properties can be seen in spectra of feather meal due to the quality of this material. Because of bright colour of feather meal its reflectance value starts from 9,7 %. In the visible (VIS) and first part of near infrared (NIR) range (until 863 nm) reflectance value of feather meal is increasing more intensively, than the previous and the subsequent range. Changes in NIR can be associated with nutritional value of the samples.

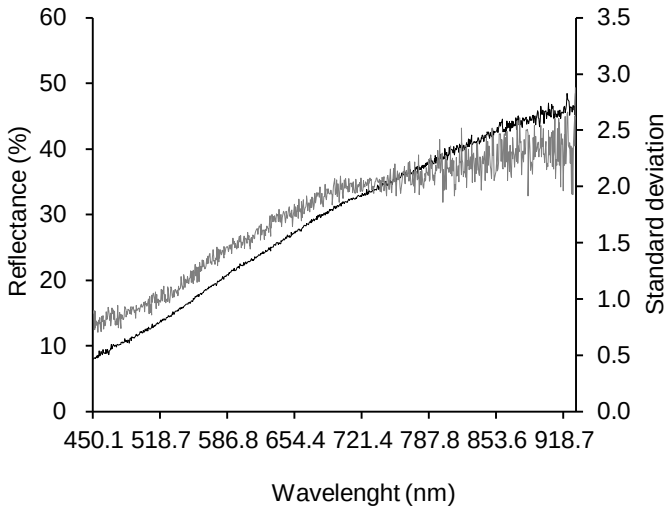

Fig 3. *Generated reflectance values and standard deviation of feather meal (black – generated reflectance value; grey – standard deviation)*

A polynomial trendline is a curved line that is used when data fluctuates. It is useful, for example, for analyzing gains and losses over a large data set. The order of the polynomial can be determined by the number of fluctuations in the data or by how many bends (hills and valleys) appear in the curve.

Polynomial trend of reflectance values of feather meal are shown in Figure 4. The R^2 value is approach to one, therefore trend of spectra of feather meal can be predicted with high accuracy.

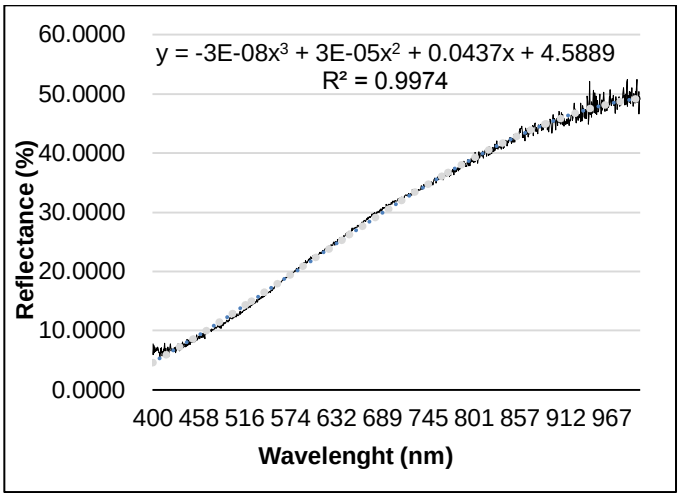

Fig 4. *Polynomial trend of feather meal (black – values of generated reflectance; grey points – values of polynomial trend)*

The results are evaluated by the ENVI 5.0. Inflection point of feather meal is determined by the software. As a result, we can determine that range of wavelenght, which is suitable to detect individual characteristics of feather meal. Analysing the samples it was concluded that inflection point of feathe meal is in range of 679-682 nm.

IV. Conclusion

Spectral analysis of wavelenght range between 400-1000 nm reflectance value of feather meal is increasing by more than 30 %. Reflectance value of feather meal between 400-420 nm is relatively low (3-10 %).

The reflectance value is increasing with increasing wavelenght and maximum values (50-55 %) are in near-infrared range, between 980-1000. Between 530-750 nm changes of reflectance values reach 10 %. Analysing the samples it was concluded that inflection point of feather meal is in range of 679-682 nm. Thus inflection point facilitate to detect individual characteristics of feather meal.

Based on preliminary measurements the method limitidly capable to measure moisture content [20](Nagy et al., 2014), thus using spectrometer between 1000-2500 nm is suggested to analyse moisture content.

Acknowledgment

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