APPLYING NIR-SPECTROSCOPY TO INDUSTRIAL SAUSAGE PRODUCTION
APLIKOVANIE NIR-SPEKTROSKOPIE V PRIEMYSELNEJ VÝROBE ÚDENÍN

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Abstrakt

Tento článok demonštruje, že H&K NIR on-line spektroskopia je vhodná na priame meranie štyroch najdôležitejších parametrov: vody, tuku, celkových bielkovín a kolagénu v miešačke párkov. V tomto prípade sa jedná o aplikáciu pre pečeňové údeniny v 1,5 tonovej miešačke s dvojitou stenou. Článok poukazuje na dosiahnuteľnosť optima štyroch súčastí, ako aj na finančné úžitky pre zákazníka pri využití NIR spektroskopie.

Kľúčové slová

NIR-spektroskopia, výroba údenín, tuk, voda, bielkoviny

Abbreviations

There are some meat industry specific abbreviation or terms (explained later in the text), which we will use here:

FW: Water value
FE: Total amount of protein in meat
BE: Collagen
BEFFE: Creatin
Water: Total amount of water
Fat: Total amount of fat
Ash: Minerals

Introduction

In Germany we have strict regulations for sausage production. For every kind of sausage the quality is defined by:

- Maximum amount of water
- Total amount of fat
- Minimum amount of protein

The uncritical parameter among this three is the fat. Depending on what kind of a particular sausage is produced the manufacturer is free in defining the fat content of the sausage (e.g. diet sausage, low fat sausage or normal sausage). The only regulation for the fat is, that the defined fat content must be regulated to +/-5%.

The water content in sausages normally is given by the water content of the used meat and the production process of the sausage, e.g. the type of sausage.

The regulations for meat production distinguish three types of sausage:

1. Raw sausage: The finished sausage is still raw meat, matured and dried. Here FW is below zero, because while drying the sausage looses water. E.g. SALAMI.
2. Scalded sausage: During production it is necessary to add ice, to stabilise the sausage. Here FW greater than zero, because of the added water. E.g. LYONER.
3. boiled sausage: During production the ingredients are boiled. Here FW is smaller or equal to zero. E.g. LIVER SAUSAGE.

For every kind of sausage the water value FW is defined by regulations. In general FW is calculated as follows:

FW = Water(%) – 4 x FE(%)

The factor 4 describes the fact, that in natural meat water and protein is approximately distribution in a ratio of 80% water and 20% protein. This reflects the biological distribution of water and protein in meat. For fresh sausage ideally FW should be zero, because then the water to protein ratio is equal to the natural water protein ratio.

The total amount of protein FE in meat mainly consists out of connective tissue free protein BEFFE, called CREATIN and connective tissue protein BE, called COLLAGEN. CREATIN is digestible and valuable for the human body. Collagen is hard to digest and therefore valueless for the human body. Therefore a high quality sausage has a high amount of CREATIN and a low amount of COLLAGEN. For every kind of sausage there is a regulations which defines the minimum amount of CREATIN and the ratio of CREATIN to COLLAAGEN in a specific sausage. Summarised we can say, that the three important parameters in sausage production are:

Water value FW
Total protein FE
Collagen BE

Liver sausage production

The regulations for a specific liver sausage are as follows:

BEFFE: $\geq$ 8%
BEFFE/FE $\geq$ 0,75
FW$\leq$0

In industrial production of sausage, the goal is to drive the production as close as possible to the regulation limits, to save the expensive raw materials. Liver sausage production is a “hot” production. That means the production process requires boiling of the mixture and due to the boiling process there is a significant amount of water evaporated from the meat. Therefore the total weight at the end of the production process is lower than at the beginning, which is indicated by a negative FW value (water evaporated). If a manufacturer would accept this, he would sell less sausage than he has purchased meat and therefore he would waste money. If it would be possible to calculate the FW value on-line, the evaporated water could be added to the final product and the profitability of the production could be increased.

From a manufacturer, producing liver sausage in Germany, we have got a request if it is possible to measure FW and protein on-line. Until now there is no on-line instrumentation on the market and the customer is searching for such an instrument. The accuracy requirements are:

Fat:	measuring range 17% - 38%;	±1%
Water:	measuring range 42% - 62%;	±1%
FE:	measuring range 10% - 18%;	±0,25%
BE:	measuring range 1% - 3,5%;	±0,25%

If it would be possible to measure with this accuracy the customer could add a significant amount of water to the final liver sausage, he could optimise the protein in the product and as an extra he would save laboratory cost. At an average price of ca. 1,4EUR per kg of meat and a daily production on 15t one percent of added water will increase to profit by ca. 210EUR per day.

Instalation

From our experience with "cold" sausage production we know, that it is possible to measure the required parameters. The big difference is, that in cold production the product temperature is almost constant and in "hot" production the product temperature varies for more than 40°C, which makes a measurement with NIR almost impossible. Therefore we agreed with the customer to stabilise the temperature during the last three minutes of the production process to a certain temperature controlled to ±2°C. During this period we want to measure. As we had no experience with this kind of mixer it was a difficult decision where to place the sensor. The mixer is double walled with water between the walls. The water is used for heating and cooling of the product. As changing the mixer is relatively expensive the customer gave us only one try to find the best position for the NIR sensor. Together with the production management we decided to place the sensor at the almost deepest point of the mixer, assuming, that at this place the mixing of the product will an optimum.

The following figure 1 shows the entire mixer together with the spice feeder. This type of mixer is one of the standard mixer types used for boiled sausage production. This specific mixer has a capacity of 1,5t per batch. The production is in average ca. ten batches per day, or ca. 15t per day.

Figure 1 Sausage mixer top view

Figure 2 Opened mixer with a view on the NIR sensor and the mixing paddle

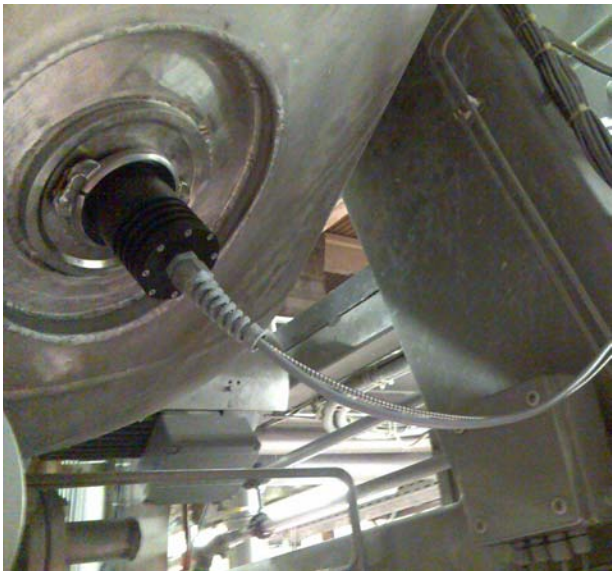

Figure 3 Outside bottom view of the mixer with installed NIR sensor

Figure 2 shows the lighted NIR sensor from the inside of the mixer and figure 3 shows the installed sensor from the outside of the mixer.

Calibration development

We tried to pre-calibrate the instrument in our laboratory with samples from the customer. In this case with no success, because liver sausage is such a critical product, that even if the samples are transported cooled, especially the protein starts to break up and the water separates from the sample. Due to this, we found no correlation between the calibration model and the samples. Therefore the only way was to install the instrument and try to calibrate the instrument on site. Calibration on site has the advantage, that the calibration samples are representative for the production, but on the other hand it is not possible to get in one day the whole variation in the required measuring range and it could take several weeks to get number of necessary samples. Therefore we decided to take samples over a period of one month and to select out of these samples the samples covering the measuring range. The customer modified the mixer control so, that we get at the end of the mixing time a start signal and the temperature during this period is controlled to 37°C ±2°. During this period we took six spectra even distributed over this three minutes. For the calibration procedure we had to deal with the following problems:

- Even at the end of the mixing the sausage mixture is not homogeneous distributed. I.e. we expect a relatively big spectral variation within one calibration sample.
- We take six spectra for the calibration, but the customer is only willing (able) to give us one average laboratory value for all six spectra.
- The sampling point is at the top of the mixer and the sensor is installed at the bottom of the mixer. Therefore the samples might be not representative for the acquired calibration spectra.
- We are calibrating under production conditions. I.e. most probably we can not cover the whole required measuring range for calibration.
- The samples are measured in an external laboratory. It takes up to two weeks to get the results.

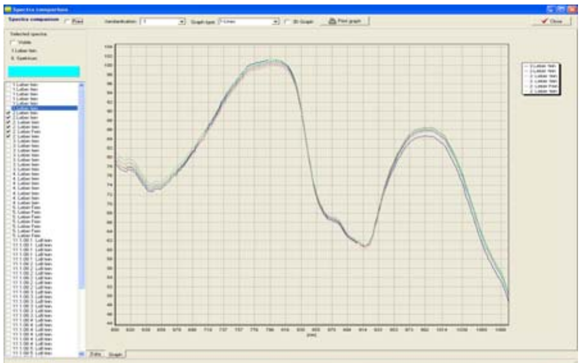

Figure 4: Spectra representing a batch with 51,8%H2O, 30,4% Fat, 13,7% FE and 1,74%BE

Figure 4 gives an impression how big the spectral variation is within one batch. Normally we should get for each of the particular spectra the constituent values. Getting only average constituent concentrations for all six spectra is one of previous mentioned problems.

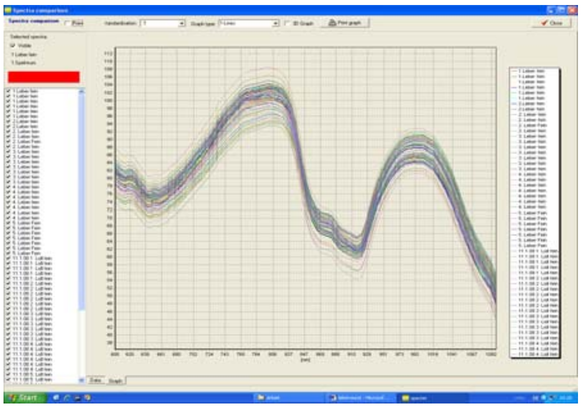

Figure 5: Spectral variation available for calibration

Figure 5 shows the spectral variation which is representative for the following product variation:

- Water: 48,4% to 53,3%
- Fat: 28,1% to 35,0%
- FE: 13,3% to 15,5%
- BE: 1,41% to 1,86%
- FW: -5,7% to -2,7%

The calibration of the instrument gave the following results:

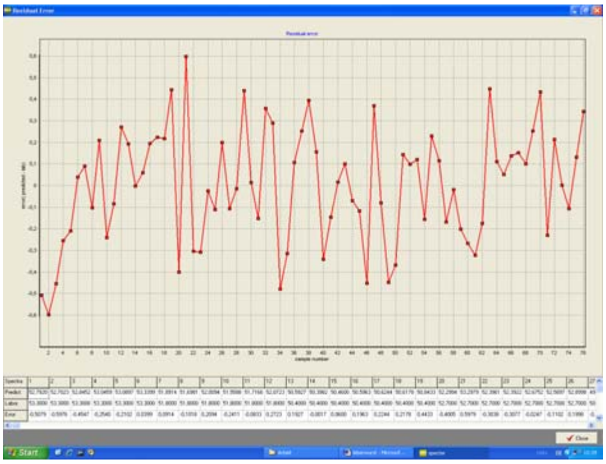

Figure 6: Water; residual error graph

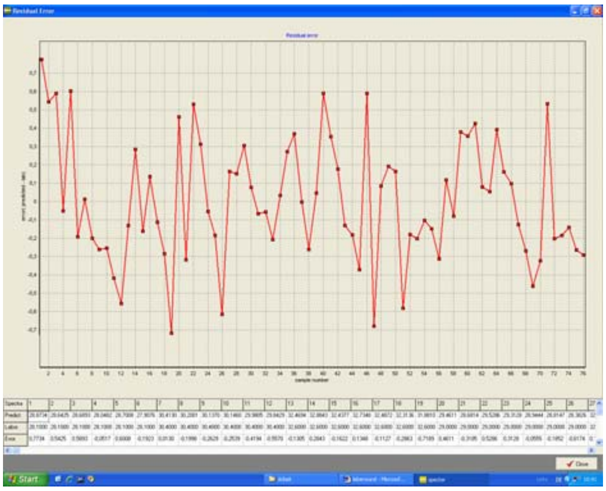

Figure 7: Fat; residual error graph

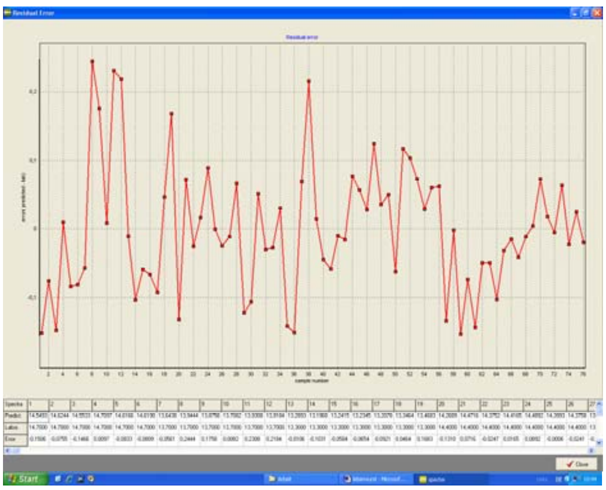

Figure 8: FE; residual error graph

Figure 9: BE; residual error graph

From the error graphs it could be seen, that the measurement fulfils the customer requirements in accuracy. We can measure:

Water: ±0,6%
Fat: ±0,8%
FE: ±0,25%
BE: ±0,25%

Profitability analysis

To proof the profitability of the installation we only focussed on the FW value. Optimising the protein content and saving laboratory cost brings additional profit for customer. We analysed in total 18 batches with a total weight of ca. 27t. The external laboratory analysis for these batches gave a FW variation from –5,5% to -2,7%, with an average of -3,81%. FW is calculated as follows:

FW = %H_2O – 4 x %FE

We know that we can measure H_2O with ±0,6% accuracy and we can measure FE with ±0,25% accuracy. We can expect for:

FW =%H_2O±0,6% - 4 x %FE±0,25%

Thus we can expect for FW an error of ± 1,6%. Assuming worst case, the maximum error is

-1,6%. Adding some safety we can say, that is possible to measure FW with a worst case accuracy of –2%. As the average FW value, give by the laboratory analysis, of the 18 batches of lever sausage is –3,81%, it is possible to add an average of 1,81% water to the finish sausage mixture. At the moment the price for one kg of low-fat meat is 1,75€ and for fat meat of 0,70€. With a fat content of ca. 30% in the sausage this results in an average price of 1,43€ per kg liver sausage mixture.

Taking the average production of 15t per day, we can expect a saving of

15.000kg x 0,0181 x 1,43€ = 388,25€/day

with a fife day production per week and an average of 4,3 weeks per month we get a yearly saving in meat of:

388,25€ x 5 x 4,3 x 12 = 100.168,5€/year

This calculation does not include the savings in laboratory cost and in cost of labour.

Summary

From the work it could be seen, that it is possible to measure the water, fat, total protein and collagen with the required accuracy. With more effort spent for the calibration mode it might be possible to measure especially water, with the same accuracy like the proteins are measured, which would allow the customer to add ca. 0,5% water to the product. What should not be underestimated is the effort spent for the calibration of the instrument. As it is unfortunately not possible to pre-calibrate the instrument, all work has to be done on-line during regular production. In the described application this procedure last about three month and required a lot of patience from the customers as well as from the instrument supplier.

References

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