

Estimation of the MEN-content of wheat for broilers by means of physico-chemical parameters and NIRS

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Abstract

Wheat is widely used in broiler nutrition. Therefore an accurate estimation of the nutritional value is essential for an optimal diet formulation. The objective of this research was to verify if the nutritional value can be estimated by means of regression equations based on physico-chemical characteristics or NIRS-calibration.

The MEN-content of the entire data-set was 11.65 MJ/kg with a variation coefficient of 3.9%. The accuracy of the prediction of MEN depended on type of regression model and harvest year with a R^2 varying from 0.04 to 0.53. On the other hand, R^2 for MEN with NIRS was 0.42 on average.

Introduction

Wheat is the most spread cereal with a share of 30% in the total cereal production worldwide. The EU (25 member states) produces yearly more than 125 millions of tonnes, of which 45% is used as animal feed. Both genetic and environmental factors and mutual interactions have a clear impact on chemical composition and nutritional value of wheat. Literature data show that the MEN-content of wheat can vary from 10.4 to 15.9 MJ/kg (Wiseman, 2000). An accurate estimation of the nutritional value is essential for an optimal diet formulation thereby influencing the zootechnical performance of broilers. The objective of this 3-year project was to verify if the nutritional value can be estimated by means of regression equations based on physico-chemical characteristics or NIRS-calibrations.

Materials and Methods

For each growing season (2000-2001-2002) 39 wheat batches were selected and analysed for their main nutrients (moisture, Cprotein as "N*6,25", cfat as petroleumether extract, cfiber, starch "Ewers/polarimetry", sugar, ash, gross energy (GE, by means of "adiabatic calorimetry") and the essential amino acids) and physical parameters (hectoliter weight "HLW" and in vitro viscosity on the supernatant after a digestion simulation with pepsine and pancreatine).

The NIRS-analysis was done with an Infralyzer 500 spectrofotometer (Bran & Luebbe), with a spectra-range from 1100 tot 2500 nm in steps of 4 nm. The 117 wheat batches were scanned in 2 forms: (1) as intact kernel in a rotating cup (\varnothing : 85 mm) and (2) after grinding (1 mm) in a static cup (\varnothing : 35 mm). Calibrations were derived from the first derivative, based on partial least square regression (PLS) with the optimal number of factors (max. 15) determined by cross-validation (20 segments). The accuracy of the calibrations was evaluated in terms of : the determination coefficient (R^2), the error of estimation by cross-validation (SECV) and the relative prediction power (RPP defined as the ratio SD/SECV).

The balance trial was carried out according to the European Reference Method (Bourdillon et al., 1990) ; consisting of a 7-day period of adaptation (14-21 days of age) and a 4-day main balance period (21-24 days of age). The MEN-content of the experimental diets was corrected for N-retention to zero but, however, not for endogenous secretions or metabolic losses. For each harvest year there were 243 experimental pens ("39 wheat batches*6 replicates" and 9 replicates of the basal diet). All wheat batches were included at 50% in substitution for all basal nutrients. All experimental diets were supplemented with an ionophorous anticoccidial.

The MEN-content of the wheat batches was calculated by means of difference "test diet vs basal diet", thereby assuming additivity. The wheat-MEN was related to the physico-chemical parameters by means of multiple linear regression analyses and to NIRS-scanning as well.

Results and Discussion

The physico-chemical composition of the 117 wheat batches is given in table 1. The data set shows that the averages of the 3 harvest years were comparable with, however, relative higher differences for e.g. Cprotein, starch, sugar and in-vitro viscosity. The MEN-content of the entire data-set was 11.65 MJ/kg on average with a SD of 0.45 (CV = 3.9%) and a range from 10.19 to 12.77 MJ/kg.

The prediction equations based on physico-chemical parameters are given in table 2. For each harvest season, there are 2 equations : the 1st being based on the 4 basal nutrients (Cprotein, Cfat, starch and sugar / with intercept or not) and the 2nd being the best model based on those parameters which significantly ($P < 0.05$) contribute to the MEN. The regression models are significant for 2000 and 2001 but not for 2002. The resp. R^2 are rather low thereby depending on the growing season. On the other hand, GE and in-vitro viscosity improve the prediction power for the season 2000 and for the entire data set.

The results of the NIRS-calibrations are given in table 3. Compared to the measurements on the intact wheat kernel, calibrations are more accurate after grinding as reflected by either a clearly lower number of PLS-factors or a higher R^2 with a lower error of estimation and higher prediction power. Only the calibrations for moisture, Cprotein and most amino acids have a high prediction power (RPA ≥ 3). In general, both moisture and Cprotein give a clear signal in the NIRS wavelength area. The RPP is moderate (≥ 1.5 en < 3) for starch, sugar, Cfat, GE, lysine, and in-vitro viscosity. Parameters with a low RPA are Cfiber, ash, hectoliter weight and MEN. In contrast to the other parameters, MEN is based on 6 replicates, thereby depending on broiler variation. The average SD was 270 kJ/kg for the test diets (50% basal diet + 50% of the resp. wheat batches) and 540 kJ/kg for wheat (as calculated by difference with transposing the entire variation to the test feedstuff "wheat"). From a theoretical point of view the accuracy of the prediction equations based on either physico-chemical parameters or NIRS can not be better than the average SD on the reference value.

The relative limited correlation between MEN and the respective parameters might suggest that these parameters were only a partly indicative for the digestion physiology and therefore other more complicated calibration parameters might be taken into consideration (Huyghebaert et al., 2005).

References

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Table 1. Wheat characteristics for the harvest years 2000, 2001 & 2002 (with 39 batches for each year)

Parameter	2000		2001		2002	
	Average	Stdev	Average	Stdev	Average	Stdev
Moisture	137.0	4.5	138.2	5.5	135.9	8.4
Cprotein	106.9	10.2	111.6	10.1	109.4	8.3
Cfat	16.8	1.7	16.4	2.2	18.7	1.9
Starch	588.0	13.2	588.2	16.2	605.5	18.1
Sugar	30.1	4.0	31.4	5.0	39.6	4.4
Ash	15.6	1.4	15.7	1.7	15.8	0.8
Cfiber	21.1	2.5	22.0	3.2	22.0	4.6
GE	16.1	0.2	15.9	0.1	16.0	0.2
MEn	11.8	0.5	11.5	0.4	11.6	0.4
HLW	77.1	2.4	78.7	2.2	77.0	3.3
Visc.	9.3	2.4	8.0	1.3	8.4	2.2
Met+Cys	4.2	0.3	4.3	0.4	4.3	0.3
Lys	3.3	0.5	3.1	0.2	3.2	0.2

Analyses in g/kg, viscosity in cps, GE and en MEn in MJ/kg, HLW in kg/hl

Table 2. Multiple linear regression equations based on physico-chemical parameters to predict MEn

Year	Regression equations : MEn (MJ/kg) =	R ²	RSD	P
2000	6.24-0.0059*CP+0.010*Cf+0.012*St-0.027*Su	0.24	0.39	<0.001
	-11.07+0.015*St+0.90*GE-0.046*visc	0.53	0.31	<0.001
2001	18.56-0.023*CP-0.032*Cf-0.0041*St-0.048*Su	0.26	0.38	0.006
	15.05-0.019*CP-0.046*Su	0.26	0.38	0.006
2002	7.90+0.0028*CP+0.0075*Cf+0.0081*St-0.042*Su	0.04	0.42	0.26
	NS			
Entire data set	9.99-0.0091*CP-0.0057*Cf+0.0063*St-0.029*Su	0.20	0.40	<0.001
	0.00826*CP+0.0017*Cf+0.0203*St-0.040*Su		0.46	<0.001
	1.54-0.012*CP-0.019*Su+0.816*GE-0.061*ash	0.27	0.38	<0.001

Analyses in g/kg for St(arch), Su(gar), CP(rotein), Cf(at) and ash. Visc(osity) in cps, GE in MJ/kg.

Table 3. NIRS-calibrations for the entire dataset (n=117), based on partial least square regression (PLS)

Parameter	Wheat in groud form				Wheat as intact kernel			
	Fact. ^a	R ² ^b	SECV ^c	RPP ^d	Fact.	R ²	SECV	RPP
Moisture	4	0.94	1.7	3.8	12	0.90	3.7	1.7
Cprotein	4	0.96	1.9	5.1	14	0.93	5.4	1.8
Cfat	10	0.77	9.8	1.8	3	0.39	16.2	1.1
Starch	7	0.83	2.7	2.3	12	0.85	4.4	1.4
Sugar	14	0.67	2.8	1.3	2	0.13	3.5	1.0
Ash	8	0.63	1.5	1.5	9	0.68	1.9	1.2
Cfiber	11	0.61	1.0	1.4	1	0.05	1.2	1.2
GE	9	0.62	0.13	1.5	9	0.65	0.16	1.2
MEn	10	0.42	0.41	1.1	2	0.18	0.43	1.0
HLW	10	0.58	2.1	1.3	5	0.69	2.0	1.4
Visc.	11	0.60	1.3	1.6	2	0.25	1.6	1.3
Met+Cys	8	0.94	0.09	3.8	13	0.89	0.23	1.5
Lys	9	0.79	0.11	1.9	7	0.69	0.17	1.2

^a Optimal number of factors by PLS-regression with cross-validation (20 segments). ^b Determination coefficient of the calibration. ^c Error of estimation by cross-validation. ^d Relative prediction power: $RPP = SD/SECV$.