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Hydration capacity: A new criterion for feed formulation

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ABSTRACT

Twenty-four raw materials, harvested or produced in 2013 and commonly used in animal feed, were used to measure their hydration capacities through both water-holding capacity (WHC, g H_2O/g DM after 24 h of water addition) and swelling capacity (SC, mL H_2O/g DM during 60 min after water addition, every 5 min during the first 30 min and then every 10 min). The raw materials were provided in the form of whole seeds (F1 class; $n = 8$), flour/mash/hulls (F2 class, $n = 8$) or pellets (F3 class, $n = 9$). Hydration capacities were measured for unprocessed material and also after grinding of whole seeds (1, 3, 5 or 8 mm grid). The raw materials were analysed for fibre content to study the relation with WHC and SC. Moreover, WHC and SC were measured on twenty-eight compound pelleted feeds containing some of the raw materials studied in the present experiment, harvested or produced in the same year (i.e. 2013; Experimental feeds; $n = 8$) or in an earlier year (i.e. <2013; Reference feeds; $n = 20$) to evaluate additivity and predictability of these criteria. WHC and SC at 60 min (T60) varied greatly among the raw materials (2.88 ± 1.74 g H_2O/g DM and 2.61 ± 2.37 mL H_2O/g DM, respectively; $P < 0.001$) and are weakly correlated ($R^2 = 0.52$; $P < 0.001$). They are thus two complementary measurements interesting in feed formulation. The physical form of the raw materials at the moment of delivery had a significant effect on WHC (0.97, 4.92 and 3.65 g H_2O/g DM in the F1, F2 and F3 classes, respectively; $P < 0.001$). Grinding the seeds had a significant effect on WHC and SC values ($P < 0.001$). WHC and SC at T60 were moderately correlated with the fibre content: neutral detergent fibre (aNDF), acid detergent fibre (ADF), acid detergent lignin (ADL), hemicellulose and cellulose content ($R^2 < 0.40$ and $P < 0.01$ the same for every fibre fraction). In the eight Experimental feeds, the correlation between calculated SC and measured SC at T60 was low ($R^2 = 0.38$; $P = 0.104$). Conversely, the correlation between calculated WHC and measured WHC was high ($R^2 = 0.89$ and $R^2 = 0.81$; in the Experimental and the Reference feeds, respectively; $P < 0.001$) and the mean difference between the predicted WHC and the measured WHC was

Abbreviations: ADF, acid detergent fibre; ADL, acid detergent lignin; D50, median particle size; DM, dry matter; aNDF, neutral detergent fibre assayed with a heat stable amylase and expressed inclusive of residual ash; F1, first class of form of presentation (whole seeds); F2, second class of form of presentation (flour/mash/hulls); F3, third class of form of presentation (pellets); SEM, standard error of the mean; SC, swelling capacity; SC_5, the volume reached at T5 (% of SC_{60}); SC_{60}, the volume observed at T60; T, volume of the sample measured before the water addition (T0) then every 5 min for 30 min and then every 10 min until 60 min (T60 end of the test); WHC, water-holding capacity.

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moderate (9.7% and 10.6%, respectively for Experimental and Reference feeds), but could reach high values (>15%), especially when measured WHC was high. In conclusion, hydration capacity could be considered as additive, however, the theoretical values of pelleted compound feeds should be supported by real measurements.

1. Introduction

Formulation of animal feeds is generally based on linear programming to meet the nutritional needs of the animals considering the availability, the price and the nutrient content of the raw materials. It considers some underlying assumptions such as additivity, i.e. the nutritional value of a compound feed is the sum of the nutrient contributions of each ingredient (Pomar et al., 2009).

Studies have shown the interest of the hydration capacity of feeds in animal feeding (Giger-Reverdin, 2000; Serena and Bach Knudsen, 2007; Jiménez-Moreno et al., 2011; Arroyo et al., 2012). Hydration capacity of feeds seems to influence the transit time, organ development (such as birds' crops), feed intake and the feeling of satiety. Although this parameter is sometimes mentioned to explain some results, it is rarely used in feed formulation as a predictive parameter. Gous (2014) noted that water-holding capacity could be a good tool to improve food characterisation models. This would require the availability of databases providing this parameter for the more common raw materials used in animal nutrition. Giger-Reverdin (2000) achieved a first screening for feedstuffs for ruminants, but raw materials used in monogastric animal nutrition are quite different. Furthermore, animals, especially monogastrics, are commonly fed with compound pelleted diets for nutritional and economic reasons (Abdollahi et al., 2013). The grinding and pelleting processes modify physico-chemical properties of the raw material and could alter accessibility of nutrients and feed intake behaviour of the animals. Therefore, the potential use of a new criterion in animal feed formulation needs to study the influence of the grinding and pelleting process and determine whether it complies with the principles of additivity and predictability.

The present study aims to measure hydration capacities, i.e. water-holding capacity (WHC) and swelling capacity (SC), for a wide range of raw materials used in compound feedstuffs for monogastric animals. These two parameters have been shown to be linked to fibre content (Bach Knudsen, 2001). Therefore, the relation between hydration capacities and fibre content was also studied. Finally, the end purpose was to evaluate whether these two parameters satisfy the principles of (i) additivity, i.e. if the hydration capacity of a feedstuff is the weighted sum of the hydration capacity of its ingredients, and (ii) predictability, i.e. if the hydration capacity of a raw material is stable enough from year to year so that hydration capacity of raw material measured here allow to predict the hydration capacity of a compound feedstuff containing raw materials coming from different delivery batches, year of harvest or production.

2. Materials and methods

2.1. Raw materials

Twenty-four raw materials were studied: oats, wheat, faba bean, corn, barley, pea, sorghum, triticale, carob, soybean hull, sunflower hull, oat bran, wheat bran, dehydrated alfalfa, wheat straw, sugar beet pulp, citrus pulp, apple pomace, sunflower meal, corn distillers' dried grains, rapeseed meal, oat hull, soybean meal and, pine lignocellulosic insoluble fibre (Arbocel R®, J. Rettenmaier and Sohne Company, Rosenberg, Germany). These raw materials were produced or harvested in 2013. At the time of delivery, they were in form of whole seeds (first physical form; F1 class: oat, wheat, faba bean, corn, barley, pea, sorghum, triticale), flour/mash/hulls (F2 class: Arbocel R®, carob, soybean hull, sunflower hull, oat bran, wheat bran, sunflower meal) or pellets (F3 class: corn distillers' dried grains, dehydrated alfalfa, wheat straw, sugar beet pulp, citrus pulp, apple pomace, rapeseed meal, oat hull, soybean meal). Whole seeds (F1 class) were studied both in unprocessed form and after grinding (1, 3, 5 or 8 mm sieve size).

2.2. Compound feeds

Additivity of hydration capacities was studied in 8 compound pelleted feeds (referred to as Experimental feeds) made from common ingredients used in animal diets (Table 3; feed no. 1) supplemented with increasing amounts of sugar beet pulp (5, 10, 15 or 20%), or 10% of soybean hull, citrus pulp or oat bran (Table 3; feeds no. 2–8). The ingredients used in the Experimental feeds came from the same delivery batches as the raw materials studied in the present experiment (i.e. 2013). They were ground using a 5 mm sieve before the mixing and pelleting processes. No steam was added during the pelleting process and the temperature at the end of the pelleting process was around 75 °C.

Predictability of hydration capacities was studied using 20 other compound pelleted feeds from previous studies in our laboratory (referred to as Reference feeds) and stored at 4 °C. Reference feeds contained the same raw materials as those cited above in varying concentrations (Table 4; feeds no. 9–28). However, in Reference feeds, the raw materials were harvested or produced in an earlier year (i.e. <2013) than those used to test hydration capacity and to produce Experimental feeds. The