GRAINS IN NUTRITION FOR FARM ANIMALS

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1.- INTRODUCTION

Grains as cultivated grasses are grown in nearly all parts of the world. The grains are very important components in the diets of farm animals and also for man. The world production a few years ago was about 2.25 billion tons of cereal grains and 330 million tons of protein meals. This production of grains was estimated to yield about 800 million tons of byproducts.

Grains have properties which makes them very suited for feeding our animals. They have a high content of energy yielding components. In addition they have a very low moisture content and they can be stored for very long periods of time if the conditions for storage are right. In Figure 1 the grain and its part are shown.

Figure 1.- Generalised scheme of a grain (taken from Kent and Everts, 1994)
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The nutritional value is most related to the starchy endosperm. The aleurone layer also is an endosperm tissue. Protein mass increases towards the periphery in the endosperm but cell sizes diminishes.

In all parts of the world cereals or byproducts from cereals are used in the diets for animals. For some classes of animals kept in confinement like in poultry the cereal wheat is even considered the most important component of feed up to now.

There is considerable variation in properties between grains which determine nutritional value (see table 1) and also within grains there can be considerable variation.

Table1.- Proportions of parts of cereal grains (%). From Kent & Evers (1994).

Cereal	Hull	Pericarp & testa	Aleurone	Endosperm	Embryo axis	Scutellum
Wheat	-	8.2	6.7	81.5	1.6	2.0
Barley	13	2.9	4.8	76.2	1.7	1.3
Oats	25	9.0		63.0	1.2	1.6
Rye	-	10.0		86.5	1.8	1.7
Sorghum	-	9.7		82.3	9.3	
Maize	-	6.5	2.2	79.6	1.1	10.6
Millet	16	3.0	6.0	70.0	5	

Wheat has a relative high protein content in the endosperm and in addition it has two populations of endosperm cells. Also rye and triticale have two kinds of endosperm cells.

Barley grains have a hull which makes up about 13 % (7 to 25 %) of the seed and winter barley has more than summer barley. Closer to the equator the hulls part decreases.

Oats endosperm cells have thicker wall than wheat and they contain some oils. In rice the husk is about 20 % of the seed. Starch granules in rice are similar to those in oats. There are many types of maize. The dent corn is the most abundant maize and is the largest of all grains. Most differences between grains are associated with endosperm character and shape. Sorghum has tannin in its pericarp and endosperm cells are similar in size and appearance as maize endosperm cells. Millet is about 1/3 of the size of sorghum.

The variation in nutritional value within and between grains has been the focus of attention of scientists in many fields. For nutritionists the focus is on factors which determine nutritional value of grains. But techniques available at present to measure all traits which do fully account for this variation in nutritional value is not all known. This paper considers some aspects of the utilisation of grains in various classes of farm animals and some reasons for variation.

2.- ENERGY FROM GRAINS IN ANIMAL FEEDING

Grains are used worldwide in animals feeding. To use the grain optimally one must match the characteristics of grains and use of the grain in the animal. Differences in feeding properties are not only associated with macroingredients like starch, protein and lipids but also with other components like non starch polysaccharides which can have a big influence due to their physical properties (see table 2).

Polysacharides in grains (CHO) consist mostly of starch. There are also other polysaccharides called the non starch polysaccharides (NSP). They form a wide range of components like pentosans (about 5.7 % in barley 6.6 % in wheat and 8.5 to 12 % in rye) and B glucans (0.6 to 4 % in various grains) see Wiseman 1990).

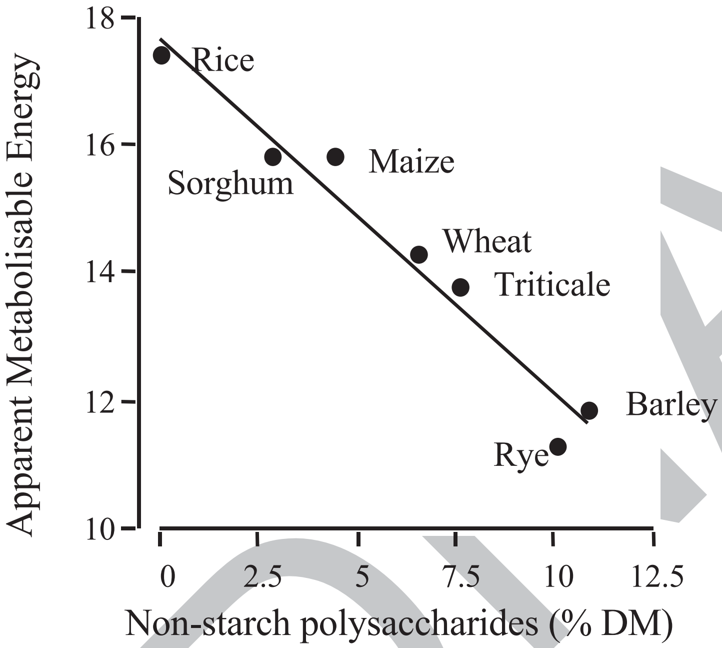
Table 2.- Carbohydrate (CHO) composition of some grains and digestibility of NSP in pigs

Feedstuff	Total CHO (%)	NSP* (%)	Starch sugars (%)	Dig of NSP in pigs(%)
Maize	73	10	63	45
Wheat	71	10	61	42
Corn gluten feed	61	39	22	46
Wheat bran	62	47	15	44

*Calculated as organic material minus crude protein, crude fat, starch and sugars and may thus include other components, such as lignins

The energy in grains available to animals can vary widely between grains and animal species. As an example for wheat in Canada Zijlstra (2005) reported a range energy contents of 14 to 19 MJ ME per kg DM for growing pigs (Zijlstra, 2005). In Australia Van Barneveld (1999) reported 13.3 to 17.0 MJ of DE per kg wheat. Similarly in broiler chickens Hughes and Choct (1999) reported a variation of 10.4 to 15.9 MJ AME per kg wheat. This is important because Hughes and Choct (1999) stated that grains and its products can make up more than 80 % of the diet for poultry For barley ranges of the same magnitude have been reported. This variation is important because cereals are mostly used for their contribution to energy metabolism. When animals differ in their capacity to digest starch from different grains this will give a different energy value. It is important to notice that it depends on the expression of energy which gives the most accurate representation of energy utilization for the animal. Worldwide different expressions for animals are used. It is clear that it is most easy to determine gross energy or calorific value (GE) of a feed. For digestibility (DE) more laborious laboratory or animal determination is needed and measurement of metabolizable energy (ME or AME) requires even more sophisticated techniques and net energy (NE) which represent energy gain in the body tissue from feed energy is the most complicated. Of this expression net energy is most near to the animal. In fact net energy is what animals deposit in their body from feed above maintenance and this is than extended to the whole feed. So energy is expressed in various ways. When based on pig data Black (2008) mentioned that feeds with the same DE content gave a variation energy deposition of 14 % , when data on ME were used this variation was 7 % and for NE the variation range was 4 %. So it must be concluded that NE is most accurate but also most difficult to measure. In Australia a large study was made on the variation in nutritional value of cereal grains across livestock. From this study it was stated (Black,2001) that there are only very small differences in the available energy content of individual grains across animals species except the low energy content of sorghum for cattle and horses.

Figure 2.- Relation between AME in broilers and Extracted NSP



The variation which exists can be mostly explained by gross chemical composition.

More recently however Gutierez-Alamo (2008) concluded from a series of studies with different wheat varieties that energy value is not accurately predicted from its physico-chemical properties. And among the variables studied she found that starch content was the variable most related to the energy value of wheat in broilers. This does not exclude that differences between grains like in physical properties associated with starch granule characteristics and endosperm matrix will contribute to variation in energy value. In poultry the NSP fraction is also associated with variation in energy value (Figure 2).

Many people have made studies on the solubility of CHO,s and their influence on the rate of digestion. Soluble carbohydrates are a property of grain CHO,s. Sugars which consist of one or two carbohydrate units are, in general, rapidly digested and absorbed by monogastric animals like pigs and poultry. Cereal grains however do not contain much ugars mostly below 5% as sucrose and fructose. Some other sugars like lactose can take a few hours before they are digested (Rerat, 1985). In most mammals lactase can be stimulated within a few days and then lactose is readily digested. In this way the pigs can eat large quantities of lactose in whey. According to (Bach-Knudsen, 1993) oligosaccharides like rhamnose, raffinose, stachyose and verbascose are poorly digested by enzymes of the pig. They can easily be degraded by micro-organisms.

Starch is readily degraded by amylase but there is considerable difference between animals in their capacity to hydrolyse starch in the small intestines. Some starch is 'resistant to amylse and is called resistant. It can be fermented by micro-organisms. Of course it then gives less energy to the animal because of losses during fermentation. This means a lower efficiency of utilisation volatile fatty acids (VFA). There is variation in digestion both between botanical sources of starch and between animals. For example, raw starch from green bananas and potatoes is digested only to 20% of the value for most cereal grains (Fuwa et al*.,* 1980). In the same way whole maize is easily digested by poultry but only 30% in horses (Kienzle et al., 1992).Therefore the susceptibility to digestion depends on the properties of the molecules in starch. One can add to that the accessibility of the starch granules. So the variation is studied extensively but has until now not led to very accurate prediction of the variation in energy of grains.

From studies on growing pigs Zijlstra et al. (1999) compiled the following table which shows the variation in digestible energy for growing pigs (table 3). As a comment the authors mention also that it would have been better to use NE for expression of energy. The reason is that the same DE can lead to different heat increments during processing in the body. So one looks now for other properties which add to the accuracy of prediction energy content.

In the Australian study the available energy content of selected grains were determined in pigs (DE), broilers and laying hens (AME). Similar to the date in the table from Zijlstra et al. (2001) there was considerable variation. But a remarkable small variation between these monogastric animals within grains was found. In table 4 some data of this study are given. The largest difference was for frosted material (1st of barley and 1st of triticale).

Table 3.- Range in DE content and energy digestibility for grower pigs and best predictor for DE content compiled from lit by Zijlstra (2001)

Ingredient	DE content MJ/kg DM	%Apparent total tract dig energy	Best Predictor
Maize	14.4-16.5	86.3-88.8	fat
Wheat	14.1-19.9	80.3-88.0	NSP
Barley	12.5-15.6	73.6-78.1	NSP
FieldPeas	14.4-17.4	84.9-93.6	fat

3.- REASONS FOR DIFFERENCES BETWEEN GRAINS

It is clear that the energy content of grains depends on what each component in the grain can contribute to energy. So it should be known how much of each component is digested. This in part depends on the availability of sufficient enzymes for digestion and also how accessible each component is for these enzymes.

Table 4.- Available energy of some grains for sheep cattle pigs DE broilers and layers (MJ/kg DM) from Black

Grain/variety	Sheep	Cattle	Pigs	Broilers	Layers
Barley	14.56	9.73	14.60	15.90	15.48
	14.79	13.21	14.83	15.98	15.96
	14.53	10.17	14.79	16.08	15.38
Barley	11.51	11.91	10.65	11.68	11.12
	13.59	13.51	13.55	13.20	13.91
	12.86	-	12.47	12.19	12.32
Wheat	13.89	13.84	13.88	13.84	13.53
	14.28	-	13.78	13.27	13.66
	14.31	14.24	14.28	14.22	14.27
Triticale	12.26	12.44	10.9112.58	11.21	11.43
	13.66	13.74		14.36	14.22
Oats	15.90	-	-	14.55	16.18
	13.41	13.33	-	13.37	14.08
	12.56	12.38	-	12.55	12.71

The range for oat grain was large (naked and normal oats).

In many studies see Black (2000) it is tried to derive the potential energy oif grains by first analyzing the gross chemical composition and by investigating how much of each component is digested. The latter can of course vary between animal species and between types of animals.

Table 5.- Digestion in broilers and in mature birds (CVB 1998)

Ingredient	Protein		Fat	
	A	B	A	B
Maize	83	81	84	93
Wheat	81	78	60	68
Barley	70	65	64	32

In the Australian study mentioned before one has made a determination of the components of NSP from grains like lignin, cellulose, arabinose (soluble and insoluble) glucans , other polysacharides , oligosacharides glucose starch protein lipid phytic acid and tannins. The components, as expected, determined most of the variation in available energy between species. But barley and wheat scored higher than the observed values. They also measured properties like viscosity and found that it was poorly related to the difference between observed and expected energy value from grains. Black reported that hardness gave additional information on energy. This can be explained by the delay in moisturising the kernel. The digestion of dietary compounds depends on the availability of enzymes capable of breaking specific chemical bonds, the ability of the enzymes to come in contact with the bonds and the length of time the enzymes are in association with the substrates. The acces starch to the enzyme may be affected by particle size, or the presence of other compounds. The rate of passage of digesta through the gut, which is affected by dietary, animal and environmental factors, can alter substantially the time enzymes have to digest dietary ingredients. This may also be the reason for differences in digestion between grains It can take a longer time the hard wheat to reach sufficient moisturizing.

Starch in grain is composed of a range of amylose and amylopectine. And this range varies widely between grain species. It is well known that grains with a high content of amylose starches are less well digested than those which have starches which mainly consist of amylopectine. In recent years researchers are becoming increasingly interested in the rate of starch digestion in addition to the level of digestion. The rate of digestion is very much lower in amylose compared to amylopectine (Petterson and Lindberg, 1997). In the study mentioned before one has found a large difference in the digestion between two starches. The difference was very large ic over 3 MJ per kg in sorghum. Also in rats these differences were found. Granfeldt et al. (1993) reported that low amylose starch was digestible in the small intestine for 0.96 compared to a level of 0.68 for high amylose maize. Especially the rate of digestion of starch decreases if there is a high content of amylase. Starch granules are imbedded in a protein matrix in the endosperm. Before the amylase can reach the starch these proteins must be degraded first. The degree to which the granules are encapsulated will influence how starch is digested in the small intestine. In addition the presence of anti-nutritional factors such as either tannins or trypsin inhibitors can have an influence. The degree of encapsulation of eg the starch granules in sorghum with kafarins is thought to be much more resistant against digestion by cattle compared to pigs and poultry (Rooney and Pflugfelder, 1986).

During the last decade, many research groups have investigated the use of grains in various animals like digestibility of energy and the NSP fraction.

For ruminants the manipulation of ruminal degradation by processing is usually aimed at reducing rumen degradability. For starch technological treatment can go in both directions and which direction depends on the feedstuff. Most processing of feedstuffs results in an increase rate of starch degradation in the rumen. Corn and sorghum which have a natural resistance against rumen degradation will react with increased degradability (Goelema and Prestlokken, 2001). This effect may not be always positive because in barley based diet the expander treatment increased rumen degradability and subsequently lower rumen pH. With expansion even a bit more than with pelleting. In the studies they reviewed it was observed that with pressure toasting an increased fraction of rumen undegraded starch. And it was suggested that this is due to protein denaturation resulting in a protective protein matrix around the starch granules. So with technology one can increase starch degradation or digestion rate but also reduce it. So grains and other products with slowly digestible starch must be treated in a different way compared to rapidly digestible starch.

4.- SUMMARY

Grains consist of a wide range of species and are worldwide used as mafosr food for humans or feed for animals In order to use these feeds optimally one must know as accurate as possible how much energy and nutrients they can deliver to the body . The increase in use of grain also increases the amounts of byproducts originating from processing when used as food for humans. Properties which determine which and how much nutrients can be delivered to the body and at the correct rate are becoming much better known. But predictions of these properties are not yet perfect.

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