GENETIC VARIABILITY OF RUMINAL STARCH DEGRADATION OF CORN HARVESTED AT TWO SILAGE MATURITIES

C. Philippeau[1], M. Champion[2] and B. Michalet-Doreau[1]
[1] SRNH, INRA-Theix, 63122 St Genès Champanelle, France
[2] Limagrain Genetics International, BP 1, 63720 Chappes, France

ABSTRACT
This trial was carried out to determine the influence of genotype and maturity stage on ruminal starch degradation of corn harvested at silage maturity. Two types of corn (*Zea mays L.*), differing in their endosperm texture, flint or dent, were harvested at 30 and 35 % whole plant DM. The degradation rate in the rumen of grains (oven dried at 40°C and ground through a 3-mm screen) was determined by the *in situ* technique. Mean ruminal starch degradability was 69 %. With maturity, the content of grain in the whole plant increased and ruminal starch degradability decreased (15 points). Starch of dent corn was always more degradable than starch of flint corn (22 points). Particulate starch losses through the bag pores were low and they varied little. Harvested at silage maturity, ruminal starch degradation of corn grain varied widely.

KEYWORDS
Digestion, rumen, corn, starch, silage maturity, genotype

INTRODUCTION
Digestion in the whole tract is the basal method to determine the energetic value of maize silage. Starch represents 30 % of the whole plant dry matter and its digestion in the whole tract is almost complete and varies little. Hence this fraction has attracted little attention unlike the parietal fraction (Verbic et al., 1995). Current research has taken a more analytical approach in terms of nutrient flows to improve knowledge of how nutrition determines the quality of the products (milk, carcass). The site of starch digestion has implications for the nature and amounts of nutrients delivered to the ruminant, volatile fatty acids in the rumen and in the hindgut and glucose in the small intestine. We showed marked variations in ruminal starch digestion between cereals (Cerneau and Michalet-Doreau, 1991) and for the same species, corn, between genotypes (Michalet-Doreau and Champion, 1995). The aim of this study was to determine the effect of genotype on the rate and extent of ruminal starch digestion of corn harvested at silage maturity.

METHODS
Two types of corn (*Zea mays L.*) differing in their endosperm texture, flint or dent, were grown in Limagne (France) under identical agronomic conditions. They were pollinated by the same male corn plant. Each genotype was cut at two stages of maturity characterized by DM of the whole plant, 30 and 35 %. The proportion of grain in the whole plant was determined after extracting the grains from 5 whole plants and weighing. Samples of grains were oven dried at 40°C for 72 hours and were ground with a hammer mill through a 3-mm screen. Their degradation rate in the rumen was measured by the nylon bag technique. Nylon bags (internal dimensions 5 x 9 cm ; pore size 53 mm) containing 3 g DM of ground corn were incubated in the rumen of 3 dry Jersey cows, fitted with a ruminal cannula, and received 6 kg DM of corn silage in two meals. They were removed after 3, 6, 9, 15, 24 and 48 h of incubation. Each time of incubation was repeated 6 times (3 cows x 2 repetitions). Starch content of corn grains and residues was determined by an enzymatic method (Faisant et al., 1995). The degradation kinetics were adjusted to an exponential model, and the effective starch degradability was calculated with a feed passage out of the rumen of 5 % h^{-1}. Effective degradability and the kinetic parameters were submitted to two-way analysis of variance, stage of maturity and genotype. Losses of undegraded particles through the bag pores were assessed by placing bags for 2 h in a buffer solution (one bag in 250 ml of solution) in a shaken water bath at 39°C. The lost undegraded particles were recovered from the solution by filtration. The filters were weighed and analysed for starch content.

RESULTS AND DISCUSSION
From 30 to 35 % whole plant DM, the proportion of grain in the whole plant increased and this increase was greater for dent than for flint maize. It was due essentially to a different time course of DM content of grain between genotypes. At the first stage, the starch content of the grain was not different but it increased more rapidly for flint than for dent corn with maturity. Mean starch degradability of corn was 69 % and decreased with maturity independently of genotype. This was due to a decrease in the rapidly degradable fraction and a lower degradable constant rate at least for dent corn. Whatever the maturity stage, starch of dent corn was more degradable than that of flint corn and the amplitude of the variation was constant, on average 22 points. The loss of particulate starch through the bag pores remained low and relatively constant, 10.4 and 11.4 % of starch initially incubated respectively for dent and flint grains. They could therefore not account for the differences in starch degradability between the two maturity stages and genotypes. For mature grain, the rate of starch degradation is considered to depend to a large extent on the accessibility of starch in the grains to microbial enzymes, i.e. on the structure of the endosperm (Mc Allister et al., 1993). Similarly, more research needs to be done at silage maturity to determine changes in the composition and structure of the protein matrix with maturity. The two genotypes of corn studied in this experiment varied in the composition of their endosperm. In corneous endosperm, starch granules were surrounded by protein bodies and a continuous protein matrix whereas in the floury endosperm starch granules were embedded in a discontinuous protein matrix. Hence, starch granules of floury endosperm were more accessible to ruminal bacteria than those of flint corn and so more degradable (Kotarsky et al., 1992). In conclusion, the *in situ* technique may be used to determine ruminal starch degradation of immature grains since particulate starch losses were low. At silage maturity the dietary starch escape could vary to a large extent, and be manipulated by genetic selection.

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Table 1
Influence of genotype and stage of maturity on the content of grain in the whole plant and the chemical composition of the grain.

Genotype	Flint		Dent	
% whole plant DM	30	35	30	35
Part of grain in the whole plant (% DM)	20.9	23.3	24.1	38.0
DM content of the grain (%)	53.9	63.3	38.7	56.0
Starch content of the grain (% DM)	62.1	67.9	61.0	63.1
Nitrogen content of the grain (% DM)	11.4	10.4	12.5	10.1

Table 2
Influence of genotype and stage of maturity of corn on starch ruminal degradation parameters.

Genotype	Flint		Dent		SEM
% whole plant DM	30	35	30	35	
Rapidly degradable fraction (%)	26.5	10.4	49.5	26.7	8.3
Slowly degradable fraction (%)	73.5	89.6	50	73.1	7.8
Degradation constant rate (%.h^{-1})	5.7	4.3	19	8.3	3.3
Effective degradability (%)	64.7	51.2	88.2	72.2	1.5