

COMPARATIVE DIGESTIBILITY STUDIES WITH HENS AND RATS

LIISA SYRJÄLÄ

University of Helsinki, Department of Animal Husbandry

Received July 22, 1970

Abstract. Trials were made to compare the digestibility of feeds in hens and rats. In the comparison particular attention was paid to the true digestibility of the feeds. The digestibility of rusks made of wholewheat meal was compared in hens and rats. The rats digested 62.1 % of the cell wall substances of the whole wheat meal, while the value for the hens was 16 %-units lower. The true digestibility of the other N-free organic matter was also clearly lower in the hen trial than in the rat trial. In the rat trials the digestibility of wholewheat meal was compared with that of bark meal. The true digestibility of the organic matter of the bark meal was only 23.6 %, while that of the wholewheat meal was 92.4 %. The digestibility of the cell wall substances of the bark meal was 18.5 % and of the wholewheat meal 62.1 %.

It is rather difficult to compare the digestibility of feeds in hens and rats, owing to the great differences in the digestive tract and excreta of these animals. If the comparison is based on the apparent digestibility values, the results can be deceptive. This is due to the fact that the quantity and quality of the endogenous and bacterial materials of faeces vary considerably in the different animal species, and also in the same species when different rations are given. With poultry the uric acid of the excreta also leads to inaccurate digestibility results, if these are based only on the apparent digestibility. If the efficiency of digestion in different animal species is to be compared, the true digestibility of the feeds of these animals has to be known. The same applies if widely differing feeds are given to the same animal species (SYRJÄLÄ 1967). In this paper the word faeces means also the excreta of the hens.

The purpose of this study was to investigate and compare the efficiency of digestion in hens and rats by estimating the true digestibility of their feeds. The feeds used in the digestibility trials were wholewheat meal and bark meal. The latter is made from the inner bark of pine.

Experimental procedure

F e e d s. The digestibility of wholewheat meal was studied in hens and rats; the digestibility of bark meal only in rats.

For the hen and rat experiments rusks containing Cr_2O_3 were made from wholewheat meal, according to the following recipe:

wholewheat meal	2 kg	yeast	100 g
NaCl	20 g	whole milk	1 l
sugar	200 g	Cr_2O_3	8 g

Cr_2O_3 , sugar and salt were first mixed together carefully, and then mixed thoroughly with the meal. After baking the bread was sliced and dried to rusks. These were ground for the hens and given whole to the rats.

The bark bread for the rats was made according to the following recipe:

bark meal	1 kg	yeast	100 g
white wheat flour	1 „	whole milk	2.5 l
NaCl	20 g	Cr_2O_3	8 g
sugar	200 g		

Bark meal was made by drying and grinding inner pine bark. The bread was not dried. The rats received it fresh. The animals ate the bread almost greedily.

Trial with hens. Four healthy hens that had finished laying were used for the experiment. The hens were kept in the same $2 \times 2 \text{ m}^2$ net-covered pen. Before the experiment the animals were accustomed to the new conditions on normal feeding. During the experiment they were fed twice a day. Chicken lime and water were given *ad libitum*. The faeces were collected twice a day. They were each time collected very carefully so that the proportion of the caecum and other excreta in the samples remained correct. The animals were given the experimental feed for 8 days, but the analyses were made only from the faeces excreted in the last two days.

Trials with rats. The experimental procedures in the wholewheat meal and bark meal trials were the same. Four rats of the same sex were used in both trials. They were kept in the same cage. The rats were weighed at the beginning and end of the trial. They had food and water *ad libitum* during the day-time and water at night. In the evening the rats were brushed lightly and moved to two net cages, under which was another closer net for the collection of faeces. Only the faeces excreted in the night, which were free from hair and food, were used for the analyses. Both digestibility trials lasted 9 days, but faeces were collected only in the last 5 days. In both trials the average weights of the rats decreased: 17 g when the animals were fed with wholewheat meal rusks and 22 g with bark bread.

Analytical methods. From the meals and ground rusks determinations were made of dry matter, ash and crude protein. Plant cell wall substances were also determined by the methods of SALO (1965 a) and PALOHEIMO and VAINIO (1965), and Cr_2O_3 from the rusks (PALOHEIMO and PALOHEIMO 1935).

Most of the stones were removed from the faeces of the hens before the analyses. All the analyses were made from fresh faeces samples. The faeces of the rats were very dry, their dry matter content being 60 %. They were prepared for the analyses by pounding in a porcelain mortar with two parts of water to one part of faeces.

From the faeces samples determinations were made of dry matter, ash, Cr_2O_3 , crude protein and plant cell wall complex. The last-mentioned was determined from the faeces samples in the wholewheat meal trials of the hens and rats by the »sinter method» and

in the bark meal trial of the rats by the »incubation method». Both methods have been developed by PALOHEIMO and SYRJÄLÄ, but are still unpublished. In the sinter method (PULLIAINEN, PALOHEIMO and SYRJÄLÄ, 1968 p. 8) the faecal exogenous material is separated from the faecal endogenous and bacterial material (PALOHEIMO 1962, PALOHEIMO 1966, PALOHEIMO, SYRJÄLÄ and VAINIO 1968) by ultrasonic treatment and sinter filtration. In the incubation method the faecal endogenous and bacterial material is dispersed with the aid of enzymes derived from the faecal bacteria by incubating a suspension of the faeces for about 20 hours at 40°C. The method also involves washing and sedimentation. The incubation method was used instead of the sinter method in the bark meal trial with the rats, because the faeces contained a large proportion of mucus, which disturbed the sinter filtration. The cell wall complex is obtained in both methods from a certain crude fraction (F-fraction) by extraction with 80 % (v/v) ethanol and using ash and crude protein corrections.

Results

Table 1 shows the chemical composition of the wholewheat meal, the bark meal and the faeces samples, and their digestibility values. Table 2 shows the amounts of the digestible nutrients per 100 g of dry matter of meals. In calculating the digestibility percentages of the meals it was supposed that all the indigestible materials in the rusk and bread were derived from the wholewheat and bark meal. This supposition is not quite correct, however, because 36.5 % of the bark bread dry matter consisted of white wheat flour. However, since only 3.7 % of the white flour consisted of cell wall substances, the major part of it being composed of more easily digestible cell enclosure substances, the error caused by this supposition cannot be great. The negative apparent digestibility of the dry matter of the bark meal, 1.3 %, shows, however, that the indigestible dry matter of the faeces was derived from other constituents of the bark bread besides the bark meal.

In compiling the four columns in the right-hand part of the tables, it was supposed that the exogenous organic matter of the faeces equals the organic matter of the F-fraction. This being so, the exogenous crude protein of the faeces equals the crude protein of the F-fraction. Further, the exogenous N-free organic cell enclosure substances equal the exogenous N-free organic matter minus the cell wall complex.

The digestibility values in the left-hand part of the tables show the apparent digestibility of the feeds, with the exception of the values of the cell wall complex, which are true. The values in the right-hand part show the true digestibility.

Discussion

When comparing the digestibility values of the whole-wheat meal trials with the hens and rats, it is advisable to consider only the values which do not include ash or crude protein. Hen excreta contain small stones and sand which are not derived from the food and these remain in the ash after incineration. The ash also contains minerals excreted through the kidneys. In addition, hen excreta contain uric acid, which accounts for the values for crude protein being too high. Another factor which makes the figures for crude

Table 1. The chemical composition of meals and faeces and the digestibility values, expressed as percentages of dry matter.

	Exogenous ²⁾									
	Ash (Cr ₂ O ₃ - free)	Org. matter	Crude protein	N-free org. matter	Cell wall complex matter	N-free org. cell enclosure substances	Org. matter	Crude protein	N-free org. matter	N-free org. cell enclosure substances
Wholewheat meal	1.8	98.2	13.7	84.5	17.4	67.1	98.2	13.7	84.5	67.1
Bark meal	2.6	97.4	3.5	93.9	74.4	19.5	97.4	3.5	93.9	19.5
Faeces:										
Hen ¹⁾ : Trial with wholewheat meal	23.0	77.0	37.0	40.0	28.8	11.2	33.4	3.0	30.4	1.6
Rat ¹⁾ : —»— —»—	7.3	92.7	30.3	62.4	38.7	23.7	44.3	3.5	40.8	2.1
Rat ¹⁾ : Trial with bark meal	5.4	94.6	18.5	76.1	59.9	16.2	73.5	10.2	63.3	3.4
Digestibility %										
Dry matter										
Hen: Rusk	73.4	— 118.2	26.2	87.2	46.2	95.7	90.8	94.1	90.3	99.4
» Wholewheat meal	67.6	— 286.6	12.9	84.7	46.2	94.6	89.0	93.0	88.4	99.2
Rat: Rusk	86.0	75.3	68.3	89.6	62.1	95.2	93.6	96.4	93.2	99.6
» Wholewheat meal	83.0	56.4	62.6	87.5	62.1	94.0	92.4	95.8	91.8	99.5
» Bark bread	60.2	42.8	37.0	64.3	24.4	87.9	69.7	65.4	70.3	97.5
» Bark meal	— 1.3	— 79.4	1.7	— 438.7	18.5	16.1	23.6	— 196.4	31.8	82.4

1) Average of 4 animals

2) Derived from food

Table 2. Digestible nutrients, g per 100 g of dry matter of meal, in different digestibility trials

	Exogenous									
	Dry matter	Ash	Org. matter	Crude protein	N-free org. matter	Cell wall complex enclosure substances	Org. matter	Crude protein	N-free org. matter	N-free org. cell enclosure substances
Hen: Wholewheat meal	67.6	— 5.7	73.3	1.8	71.5	8.0	87.4	12.8	74.6	66.6
Rat: Wholewheat meal	83.0	0.5	82.5	8.6	73.9	10.8	90.7	13.2	77.5	66.7
» Bark meal	— 1.3	— 2.9	1.6	— 15.3	16.9	13.8	23.0	— 6.8	29.8	16.0

protein excessive is the high N content of the uric acid, which is 33.3 %. This means that the N content of the crude protein is over 16 % and that the coefficient of 6.25, used in calculating the crude protein, is consequently too high.

The plant cell wall complex fraction of the faeces determined by the sinter method is relatively free from endogenous material, including uric acid. The values of the cell wall complex are also protein-corrected and ash-free. It can thus be seen that only the values for plant cell wall substances and the other figures showing the true digestibility can be used when comparing the efficiency of digestion in hens and rats.

Table 1 shows that the digestibility of the cell wall substances of the wholewheat meal is 16 %-units higher in the rats than in the hens. In the case of the exogenous organic and the N-free organic matter, the values are about 3 %-units higher in the rats, while the digestibility values of the exogenous N-free organic cell enclosure substances are about same in both species and very high, about 99 %. When the hens consume 100 g of the dry matter of the rusks, they lose 11.6 g of organic matter in the endogenous fraction of the faeces. The corresponding figures for the rats is 6.8 g.

A comparison of the digestibility of the wholewheat meal and the bark meal in the rats shows that they digested 62.1 % of the former and only 24.4 % of the latter. This is due to differences in the composition of the cell wall substance fraction (SALO 1965 b, SALO and KOTILAINEN 1969), which are shown as percentages in the following tabulation:

	in whole wheat meal	in bark meal
cellulose	8.6	35.4
hemicellulose	47.1	31.3
crude lignin	9.2	18.8
other cell wall substances	35.1	14.5

The value for the »other cell wall substances» is calculated by subtracting from the cell wall complex determined by the method of PALOHEIMO and VAINIO (1965) the fractions of the cellulose, hemicellulose and crude lignin (SALO 1965a). The remaining fraction includes uronic acid anhydrides. The value can be calculated in this way because the cell wall substance fractions determined by the methods of Paloheimo and Vainio and of Salo do not differ very much from each other. Lignin, which is practically indigestible, protects other cell wall substances and cell enclosure substances against the digestive enzymes. This is probably why the digestibility of the exogenous N-free organic cell enclosure substances is 99.5 % in the wholewheat meal, and only 82.5 % in the bark. It also explains why the digestibility of the exogenous organic matter is high, 92.4 %, in the wholewheat meal, and low, 23.6 %, in the bark meal.

It may seem surprising that the digestibility value of the exogenous crude protein of the bark meal is negative. This is apparently partly due to the protective effect of the cell wall constituents, but also to the fact that a part of the correction for protein made to the cell wall fraction relates to endogenous and N-rich mucus, which was very abundant in the faeces obtained in the bark meal trials. When the rats consumed 100 g of the dry matter of bark bread they lost 8.4 g of endogenous organic matter, while in the case of the rusks made of wholewheat meal the corresponding loss was 6.8 g.

The chemical composition of bark meal made from the inner bark of pine is different from that of pine wood (SALO 1965b, SALO and KOTILAINEN 1969).

The following tabulation shows the percentage composition of the dry matter of bark meal and pine wood.

	in bark meal	in pine wood
ash	2.6	0.2
crude protein	3.5	0.6
crude lignin	14.0	25.1
cellulose	26.3	39.6
hemicellulose	23.3	14.7
other cell wall substances	30.3	19.8

The percentages of the different sugar anhydrides in the hemicellulose fraction are as follows:

	in bark meal	in pine wood
mannose	0	40
xylose	15	30
arabinose	45	10
glucose	20	10
galactose	20	10

The above figures show that pine wood contains much larger amounts of poorly digestible crude lignin and xylose anhydrides (SALO 1965a) than bark meal, while the more easily digestible arabinose, glucose and galactose anhydrides constitute 85 % of the hemicellulose of bark meal. In pine wood the corresponding percentage is only 30. This probably explains why man is able to utilize bread made of bark. TIGERSTEDT (1919) has shown that the apparent digestibility of dry matter in man is 9.3 %.

A c k n o w l e d g e m e n t s . I wish to express my thanks to Professor emeritus Lauri Paloheimo for his valuable advice during the work, and to Miss Pirkko Myllykangas, B. Agr., for the technical assistance.

REFERENCES

- PALOHEIMO, L. 1952. Food analysis and the evaluation of foods. *Nordisk jordbruksforskning* 44: 78—86.
 —»— 1966. Some remarks on the digestion trials. *World Rev. Anim. Prod.* 2: 86—91.
- PALOHEIMO, L. & PALOHEIMO, I. 1935. Eine photometrische Methode zur Bestimmung der Cr_2O_3 bei Verdaulichkeitsuntersuchungen nach sog. quantitativen Indikatorverfahren. *Tierernäh.* 7: 317—342.
- PALOHEIMO, L. & VAINIO, K. A. 1965. Determination of the complex of cell wall substances in plant products. *J. Scient. Agric. Soc. Finn.* 37: 305—312.
- PALOHEIMO, L., SYRJÄLÄ, LIISA & VAINIO, K. A. 1968. Studies on the faeces. *J. Scient. Agric. Soc. Finn.* 40: 237—2461.
- PULLIAINEN, E., PALOHEIMO, L. & SYRJÄLÄ, LIISA. 1968. Digestibility of blueberry stems (*Vaccinium myrtillus*) and cowberries (*Vaccinium vitis-idea*) in the willow grouse (*Lagopus lagopus*). *Annales Academiae Scientiarum Fennicae Series A. IV. Biologica* 126: 1—14.
- SALO, M.-L. 1965a. Determination of carbohydrate fractions in animal foods and faeces. *Acta Agr. Fenn.* 105: 1—102.
 —»— 1965b. On the content of cell-wall constituents in various plant materials. *J. Scient. Agric. Soc. Fenn.* 37: 127—134.
- SALO, M.-L. & KOTILAINEN, K. 1969. On the carbohydrate composition and nutritive value of some cereals. *J. Scient. Agric. Soc. Finn.* 42: 21—29.

- SYRJÄLÄ, LIISA. 1967. Kettoaineiden kokonaispaljouden määrittäminen rehuista ja sonnasta sekä sulavuus eri eläinlajeilla. Lisensiaattityö. Helsingin yliopiston kotieläintieteen laitos. Helsinki.
- TIGERSTEDT, C. 1919. Über den Nährwert der Fichtenbaumrinde beim Menschen. Öfversigt af Finska Vet.-Soc. Förh. LXI, 16: 1—26.

RUOANSULATUKSEN VERTAILUA KANOILLA JA ROTILLA

LIISA SYRJÄLÄ

Helsingin yliopiston kotieläintieteen laitos

Selostetuilla kokeilla verrattiin kanojen ja rottien ruoansulatuskyvyn tehokkuutta. Sulavuuksia verrattaessa kiinnitettiin huomiota rehun todelliseen sulavuuteen.

Kanoilla ja rotilla oli vertailun kohteena sama kokojyvävehnäjäuhosta valmistettu korppu. Rotat sulattivat kokojyvävehnäjäuhon kettoaineesta 62.1 %, kun taas kanat 16 %-yksikköä vähemmän. Myöskin muiden typtöttömien orgaanisten aineiden todellinen sulavuus oli kanakokeissa selvästi alhaisempi kuin rottakokeissa.

Rottakokeilla verrattiin toisiinsa kokojyvävehnäjäuhon ja pettujauhon sulavuutta. Etupäässä näiden aineiden erilaisesta ligniinipitoisuudesta johtui, että pettujauhon orgaanisen aineen todellinen sulavuus oli vain 23.6 %, kun taas kokojyvävehnäjäuholla se oli 92.4 %. Kettoaineiden sulavuus edellisessä tapauksessa oli 18.5 % ja jälkimmäisessä 62.1 %.