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Ileal digestibility values and their practical application

Wartości strawności jelitowej i ich praktyczne zastosowanie

INTRODUCTION

Intensive investigations of the ileal digestibility carried out for the last two decades raise hopes in more precise evaluations of amino acids contents in formulated diets to achieve an optimal growth of the animals. Several research institutes have dealt with and still are engaged in this subject employing different investigation techniques and try to put the evaluated digestibility values into practice. Only a few authors indicate an inexpediency of using ileal digestibility values in a case when e.g. approximately the same ingredients were used in formulating diets as were used in determining the amino acids requirement (26, 22). The majority of investigators recommend, in practice, to utilise rather ileal digestibility values than the total (faecal). Moreover, firms such as Eurolysine or Rhone-Poulenc offer tables (Tab. 1) listing already estimated ileal digestibility values of the most commonly used food ingredients, containing indications how to use them in practice (3, 4).

The aim of this review is to evaluate the accuracy of each step of a diet formulation and to discuss the usefulness of using ileal digestibility values as to increase its precision.

CHEMICAL ANALYSES

According to the AFRC report (1), the results of the total nitrogen estimation by Kjeldahl method differ mainly in respect of the catalyst used, i.e. copper sulphate vs. mercury oxide. Mercury catalyst usually gives higher results and a more accurate estimation than copper sulphate. To convert the estimated nitrogen into the protein content, various factors are employed: the flour milling trade uses a constant factor

Tab. 1. Apparent ileal digestibilities values (%) of nitrogen and indispensable amino acids in barley

	1	2		3		4	5
	(n = 1.7-2.2)	Mean	Range	Mean	Range		
Nitrogen	66.5-72.6	74.5	68.6-77.1	71.0	53.0-80.0	70.0	70.0
Lys		72.3	64.9-79.0	72.0	57.0-86.0	64.3	67.0
Met		79.8	72.1-88.0	-	-	77.9	79.0
Cys		-	-	-	-	74.4	74.4
Thr		69.0	64.4-76.0	67.0	54.0-81.0	67.2	63.0
Trp		72.0	67.0-76.0			-	73.0
Ile		78.2	75.6-83.0			72.0	73.0
His		78.7	74.3-83.0			77.0	71.0
Leu		80.4	78.2-82.0			76.1	75.0
Phe		81.4	77.8-83.0			78.8	78.0
Tyr		-	-			74.2	-
Val		74.3	67.7-80.0			68.8	71.0
Arg		80.4	77.0-83.0			76.6	75.0

1 – Buraczewska et al. (5), 2 – Sauer, Ozimek (24), 3 – Jorgensen, Just (19), 4 – Anonym (4), 5 – Anonym (3).

of 5.7, the dairy trade a factor of 6.38 for milk and milk products and the feed trade one of 6.25. The authors of the report stated that the use of an inaccurate average constant in the calculation of crude protein suggests that in measuring Kjeldahl nitrogen an excessive concern about the accuracy of different techniques is misplaced. Regarding amino acids analyses the biggest problem still creates the trypto-phan analysis, however, the other amino acids analyses results often contain analytical errors. To reflect this statement the above mentioned authors pointed out the differences in lysine content of different wheat samples with different origin, which varied slightly in their N-content. The range of means was from 2.44 to 3.25 g Lys/16 g N. The authors stated that some of these variations reflect analytical errors that accompany the adaptation of the complex procedure to a routine basis.

ILEAL ANALYSES METHODS

According to Low (22), the investigation of the digestive physiology of pigs by means of an early form of cannula was in progress in England in the middle of the nineteenth century. Since then different research groups have developed different cannulation techniques and a lot of experiments have been done in this field. Owing to the cannulation of intestine several important observations have contributed to explain the mechanisms of digestion.

Tab. 2. Apparent ileal digestibilities values (%) of nitrogen and indispensable amino acids in soy-bean meal

	1 (44% CP)		2 (37% CP)		3 (44% CP)	4
	Mean	Range	Extruded	Toasted		
Nitrogen	81.6	79.3-85.3	84.1	73.7	80.0	81.7
Lys	86.7	85.0-89.2	88.0	77.7	86.0	85.6
Met	85.3	77.1-90.2	83.8	75.0	85.0	-
Cys	-	-	80.8	77.0	74.0	-
Thr	76.9	72.9-81.1	83.0	78.1	76.0	80.1
Trp	81.1	77.5-84.2	-	-	80.0	-
Ile	83.2	81.5-84.8	86.5	74.0	83.0	85.8
His	87.1	83.5-89.6	88.0	80.4	86.0	88.2
Leu	82.2	80.8-85.0	87.0	76.4	83.0	85.5
Phe	86.1	83.4-88.4	86.8	76.0	85.0	83.9
Tyr	-	-	87.2	77.7	-	83.4
Val	81.8	80.2-83.6	83.1	74.5	81.0	81.9
Arg	90.5	88.9-91.9	91.8	82.0	90.0	91.8

1 - Sauer, Ozimek (24), 2 - Anonym (4), 3 - Anonym, (3), 4 - Imbeah et al. (16).

The suitability of this technique for routine measurements of amino acids digestibility in practical use was one of the main aspects of its development. Each new technique was thought to eliminate the disadvantages of the previous one.

The most commonly employed cannulation technique working with simple T-cannula implies several concerns in respect of possible shortcomings of the applied digestibility markers and in obtaining representative digesta samples. Sauer et al. (24, 25) have discussed various methodological problems concerning the ileal digestibility estimation (Tab. 2). They refer to the frequency and duration of sampling in relation to the time and frequency of feeding, the internal diameter of the cannula, the amount of collected digesta samples, the dry matter content and viscosity of digesta, the fiber content of the diet and its grade of grinding. In respect of the latter the experimental diets usually are finely ground (1 mm mesh screen) which does not adhere to practice. The above mentioned authors have stated that the digestibility of the indispensable amino acids were higher ($p < 0.05$) in finely ground (1 mm mesh screen) than in cracked wheat.

Re-entrant cannula indeed allows the total sampling of digesta but the studies often are hampered by blockage problems. The extent to which blockage occurs depends on the factors already stated.

Darcy et al. (8, 9) have developed the ileo-colic post-valve (IPCV) procedure as a further improvement of cannulation technique compared to ileo-ileal or ileo-caecal re-entrant cannulas. Based on the experience with IPCV technique, the authors finally stated that it should be reserved for laboratory use only (10).

Tab. 3. Indispensable amino acid balance relative to lysin

	1	2	3	4	5	6
Lys	100	100	100	100	100	100
Met + Cys	50	60	50	50	40-64	63
Thr	60	60	60	60	53-64	72
Trp	15	18	18	15	12-18	18
Ile	55	60	50	55	44-71	60
His	25-41	26	33	33	26-40	-
Leu	100	72	100	100	86-100	110
Phe + Tyr	96	100	100	96	94-105	120
Vall	70	70	70	70	61-70	75
Arg	-	29	-	-	-	-

1 – ARC (2), 2 – INRA (17), 3 – Cole (7), 4 – Fuller (11), 5 – Low (21), 6 – Wang, Fuller (27).

Searching for a routine solution in the rapid evaluation of food ingredients allowing more precise diet formulation on the basis of digestible amino acids, Fuller and Livingstone (11) have proposed the ileo-rectal anastomosis technique. This method, also called ileo-rectal shunt (IRS), offers a few variations which are described in the review of Sauer et al. (25). The authors of this review pointed out that IRS pigs consume about two to three times more water than normal pigs and that the diets should contain a higher amount of NaCl and NaHCO₃ to compensate for the sodium losses.

Another issue is concerned with the endogenous nitrogen estimation. A measurement of the proportion of endogenous nitrogen in the digesta passing different segments of the digestive tract is impossible because there is no way to distinguish precisely exogenous from endogenous components of the digesta. Moreover, the existence of the gut microflora in the whole digestive tract influences this estimation. In an experiment with pigs Jensen (18) found the highest microbial activity in the last third of the small intestine and in the caecum. The total microbial activity in the small intestine was as high as in the large intestine. An addition of fiber to the diet significantly increased the microbial activity in the stomach and in the large intestine.

All above mentioned technical problems influence the precision of estimation. Another source of errors might result from the health state of the experimental animals. The simple T-cannula technique is believed to create no harmful effects to the animal or, as Sauer et al. (25) stated, more physiological state is maintained compared to the re-entrant cannulation. Although the re-entrant cannulation is connected with the transection of the small intestine and a disruption of the myoelectric complex, in all kinds of cannulation the motility of the small intestine is significantly disturbed. Those parts of intestine with inserted cannulas grow together with the peritoneum and the abdominal wall. According to Kipnowski (20), our today's knowledge about the motility and the mechanisms of regulation

of the human's small and large intestine is not sufficient. In this regard it is difficult to define a pathophysiologically clear systematic scheme of motility disorders. The only clinically relevant symptoms and illness which partially or nearly completely originate from motility disorders of the intestines are different forms of obstipation, irritable colon and ileus.

The digesta flow is influenced by the pressure in the gut. Therefore, it often happens, that about one - two weeks after the operation of an animal, there occur leakages of digesta around the cannula caused by the pressure in the gut. According to L o w (22), attempts which had been undertaken to maintain the pressure in the duodenum lumen during the collection from re-entrant cannulas, caused lower nitrogen flows than those measured in a free drainage system at room pressure.

D a r c y et al. (9) consider the disadvantages of the ileo-colique-post-valve technique to be due to the diminution of the caecum surface as a necessity of surgical technique. Moreover, the caecum theoretically is regarded to be a place of initiation of reflexes regulating the ileo-caeco-colique transit. The surgical intervention might influence this phenomenon.

The most pathological state of experimental animals evidently is caused by the IRS technique. In the experiment of B u r a c z e w s k a et al. (6) on pigs with permanently disconnected large intestine, the animals showed severe growth disturbances and signs of avitaminosis.

As a result of histological studies of the different parts of the digestive tract and the measurement of their weight in relation to empty body weight H e n n i g et al. (15) found no differences between normal pigs and pigs prepared with IRS technique.

The ileo-rectal or ileo-anal anastomosis are surgery techniques used in human medicine in the treatment of e.g. colitis ulcerosa. These techniques are used in particularly serious cases only, when other treatments are unsuccessful or there exists danger of the patient's life (13, 23). The role of the large intestine seems to be more complicated than to consider it just a part of intestine which can be eliminated *ad libitum* and replaced by extra supplementation of water, NaCl and NaHCO₃. According to K i p n o w s k i (20) the absorption and secretion in the large intestine depend on hormonal and neurohumoral regulations. This is the reason why, apart from maintaining the fluid and electrolyte balance as a post-operative care of patients undergoing an elimination of the large intestine, H a r d y (14) regards a supervision of a corticosteroid medication to be just as important. In this aspect the investigations of the physiological state of an anastomosed animal based on the comparison of the organs weight (15) seem to be not properly chosen.

ILEAL DIGESTIBILITY VALUES

Barley and soya bean meal are the two most commonly used food ingredients. Although other ingredients are of the same importance regarding a diet formulation,

the variation of ileal digestibility values of these two found in the literature is shown exemplary. Tables 1 and 2 compile the apparent ileal digestibility of barley and soya bean meal respectively.

Sauer and Ozimek (24) have pointed out that, apart from methodological differences, variations in amino acid digestibilities of foodstuff may also result from a large number of factors including the variety of grain, the content of crude fiber and the so-called anti-nutritional factors (tannins, lectins and trypsin inhibitors), an application of fertilizers and environmental conditions.

AMINO ACIDS BALANCE

In practical diet formulation lysine, sulphur-containing amino acids, threonine and tryptophan are considered to be the most important amino acids. In the case of a diet with a low protein content, supplemented with synthetic amino acids, for the pigs that possess the ability of higher deposition of protein, the other essential amino acids should be respected to the same extent. Supposing that a nutritionist intends to calculate the mentioned diet, he faces an assortment of various literature sources being at his disposal, listing different amino acids requirements for the same kind of animal. As an example Table 3 presents the differences one can find in the literature between the recommended values of the amino acids balance in relation to lysine. Depending on the literature source the range between the recommended values show the range of overestimation of amino acids requirement.

CONCLUSIONS

All the above mentioned issues refer to the grade of inaccuracy one has to face in practical diet formulation. The lack of precision resulting from chemical analyses, divergences of amino acid requirement recommendations, methodological inaccuracies and differences of ileal digestibility estimations exclude the apparent superiority of ileal digestibility values in comparison to faecal digestibility values.

Regarding the cannulation techniques and especially IRS pigs the question arises about the physiological state of pigs. The IRS technique, used as a necessity in human medicine to save the patient's life, may be adapted to normal, healthy pigs and then the results, obtained from surgically and physiologically changed pigs, are thought to be adapted to normal pigs with the intention to achieve their optimal growth.

According to the literature, the cannulation of an animal presents only one of the technical problems which up to now seems to be too complicated to be solved. There is no clear evidence that the surgical preparation of animals, with the aim of estimating the ileal digestibility of different foodstuff for practical use, is superior to the methods based on the faecal analysis.

Thus the surgical methods should be limited to indispensable investigations regarding physiological mechanisms of the digestive tract. The prediction of N digestibility in foodstuff by *in vitro* tests seems to be a future goal in the field of digestibility estimation.

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STRESZCZENIE

Dokonano przeglądu i krytycznej oceny literatury związanej ze stosowaniem chirurgicznych technik kaniulacji przewodu pokarmowego u świń w odniesieniu do precyzji oznaczeń współczynników strawności jelitowej, jak też stanu fizjologicznego operowanych zwierząt. Wydaje się, że dokładność oznaczeń strawności jelitowej wykonanej przy zastosowaniu technik chirurgicznie nie jest wyższa od oznaczeń w kale. W związku z patofizjologicznym stanem operowanych zwierząt i brakiem większej dokładności postulowane jest stosowanie metod oznaczania strawności w kale.