KRMIVA

PIGMEAT QUALITY AND THE DIET

KAKVOĆA SVINJSKOG MESA I HRANA

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Scientific review - Pregledno znanstveni članak
UDC: 636.4.;636.084.502.3
Received - Primljeno: 20 may - svibanj 2002.

SUMMARY

Meat quality has many aspects but from the nutritionist's point of view they may be considered as:

1. *The relative proportion of tissues* For example, fat/lean. This very much influences the visual appearance of the meat.

2. *The organoleptic properties.* For example, taste and flavour are important to the consumer.

3. *Safety.* Consumer surveys have invariably shown safety to be of greatest importance. Questions are raised continuously about residues in the meat and additives in the diet.

4. *Health promoting effects.* The modern consuming public is very well informed about dietary and other factors which may positively benefit their health.

Clearly this is a big issue, so a few selected examples will be given. In achieving the objectives of quality it is important that this is done in a way that is financially beneficial to the farmer.

LEAN MEAT PRODUCTION

An important function of animal production is to supply high quality protein for human food. In order to do this the animals themselves require high quality proteins in the correct quantities in their diets. There are many measures of protein quality (e.g. Biological Value) but all are related the supply of the limiting amino acid. Consequently amino acids are the key consideration in protein nutrition of animals. For convenience, amino acids are regarded as essential or non-essential. Essential amino acids are those which cannot be synthesised or cannot be synthesised quickly enough by the animal. These consequently form the basis of measures of protein quality.

PROTEIN REQUIREMENTS

The requirements of the animal will be influenced by many things for example species, genotype, sex, liveweight and productive function. The objective is to match nutrient supply with these factors.

THE CONCEPT OF AN IDEAL PROTEIN

In order to rationalise amino acid requirements into a form which was easily applicable by the

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nutritionist and, at the same time, overcome the problem of unwanted deficiencies of a single amino acid. Cole (1978) introduced the concept of an ideal protein. This uses growth in pigs as an example but is equally applicable to other species and other production functions. Amino acid requirements would depend on the needs of maintenance and production. As maintenance needs only account for 1B3% of the total, the major difference in requirement between pigs growing at different rates and between pigs of different sexes, breeds and liveweights is in the amount of protein that they require, according to their different potentials for lean desposition. The relative amounts of the different essential amino acids needed for the deposition of l g of lean should be the same in each case. Thus, it should be possible to establish an optimum balance of essential amino acids for growth which when supplied with sufficient nitrogen for the synthesis of non essential amino acids, would constitute the "ideal protein". Pigs of different classes (i.e. liveweight, sex, breed, etc.) would require different amounts of the ideal protein but the quality of the protein would be the same in each case. Within the range of ingredients available there may be occasions when it is not possible to achieve an optimum balance of amino acids to provide the ideal protein. For example, in attempting to meet the nutrient specifications of a diet from a particular range of ingredients an individual amino acid may be undersupplied or oversupplied. These considerations have, in recent years, needed further consideration as an oversupply or imbalance causes additional introgen excretion leading the pollution. The needs of performance and environment are entirely compatible which aiming for an optimum dietary situation.

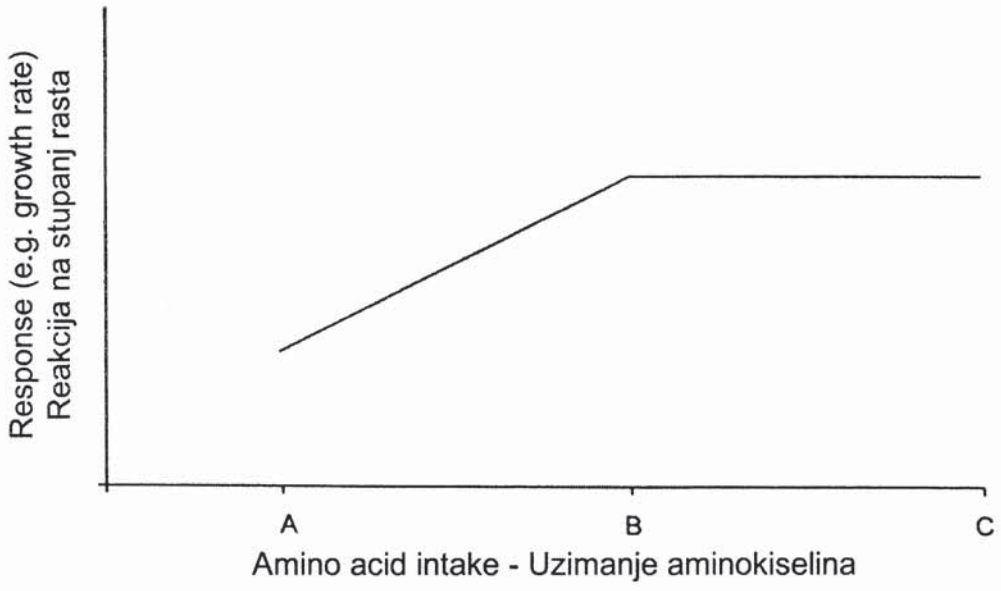
Thus, in studying the response to an individual amino acid three factors need to be established.

1. The level of supply of an amino acid at which the maximum response is achieved (Figure 1: point B). The combination of these values for individual amino acids will give the optimum balance needed for the ideal protein.

2. The consequences of undersupply of an individual amino acid (Figure 1: the slope of the response when the dietary supply is increased from A to B).

3. The consequences of oversupply of an individual amino acid (Figure 1: the change in response when dietary supply is increased markedly above the optimum, e.g. from B to C).

Figure 1. Response to changes in the dietary supply of an amino acid
Slika 1. Reakcija na promjene opskrbe aminokiselinama u hrani



In studying the response to an individual amino acid it is important to do this with diets that have no limitation arising from a deficiency of other essential amino acids, non-essential nitrogen, other nutrients or energy.

THE BALANCE OF ESSENTIAL AMINO ACIDS

The original balance of essential amino acids for the ideal protein (Cole, 1978) and used by ARC (1981) to develop its recommendations (Table 1). A function of this chapter is to examine the durability of the data and to report similar figures for other species. Perhaps the notable changes for pigs are likely to be slight increases in the ratios of methionine + cystine (up to 55%) and threonine (65%).

AVAILABILITY

The values in Table 1 are based on total amino acids and it can be questioned whether or not benefit would be derived from expressing the results in available terms. In the original proposals (Cole, 1978; ARC 1981) it was a positive decision not to represent the ideal protein in this way. The reasoning was that the measures of availability being used were, because of the variable answers that they gave, likely to increase errors rather than to eliminate them as the ideal protein was designed to do.

Recently, ileal digestibility has been used as a measure of availability. Under many circumstances such a relationship is sound (for example, Tanksley and Knabe 1984). However, there are situations when this is not the case. Batterham, Anderson, Baigent and White (1990) showed that lysine retention as a proportion of the ileal digestible lysine intake was influenced by dietary lysine concentration (Table 2).

IDEAL AMINO ACID PATTERNS

Table 1. The optimum balance of essential amino acids in the ideal protein for growth of pigs (relative to lysine=100).

Tablica 1. Optimalna ravnoteža esencijalnih aminokiselina u idealnoj bjelančevini za rast svinja (odnos prema lizinu=100)

Cole	Author(s) - Autor(i) Fuller et al		ARC	Proposed balance Predložena ravnoteža
Amino acid - Aminokiselina	(1978)	(1979)	(1981)	(1995)
Lysine - Lizin	100	100	100	100
Methionine + cystine Metionin+cistin	50	53	50	50-55
Tryptophan - Triptofan	18	12	15	18
Threonine - Treonin	60	56	60	66
Leucine - Leucin	100	83	100	100
Valine - Valin	70	63	70	70
Isoleucine - Izoleucin	50	50	55	50
Phenylalanine + tyrosine Fenilalanin + tirozin	100	96	96	96
Histidine - Histadin	40	31.5	-	33

Table 2. Responses of pigs given diets formulated from 0.1B0.72g ileal digestible tysine/ MJ DE over the 20B45kg growth phase (Batterham, Anderson, Baigent & White, 1990)

Tablica 2. Reakcije svinja koje se dobivale obroke pripremljene od O.1BO. 72 g lizina probavljivog u ileumu/MJ DE iznad razdoblja rasta od 2OB45 kg (Batterham, Anderson, Baigent i White, 1990)

Ileal digestible lysine/MJ DE (g) Lizin probavljiv u ileumu /MJ DE (g)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.72	SEM
Gain (g/day) - Prirast (g/dan)	176	392	481	561	658	688	730	717	12.5
Feed conversion ratio - Omjer konverzije hrane	5.31	3.26	2.77	2.38	2.06	2.0	1.93	1.88	0.111
Lysine retained: ileal digestible lysine intake - Zadržani lizin: unos lizina probavljivog u ileumu	0.14	0.53	0.58	0.66	0.67	0.61	0.52	0.49	0.033

A further example is in the case of heat damaging fish meals. In a study at the University of Nottingham (Wiseman, Jagger, Cole and Haresign, 1991) overheating fish-meals resulted in a reduction in both faecal and ileal digestibility of lysine (Table 3) and other amino acids. However, formulation of diets on the basis of either type of digestibility, while giving better performance, did not completely account for the problems of heat damage (Table 4). This lends support to the argument that amino acids can be absorbed in a form that is unavailable to the animal. Lysine is usually the most important amino acid damaged by heat treatment and the Maillard reaction is the most commonly reported effect of this type. In this case lysine is rendered unavailable, for example, by the production of fructose-lysine at temperatures as low as 70°C for 3h. The consequences are the inhibition of trypsin with perhaps only 10% of the lysine being released from the peptide chain and a slower rate of absorption. In rats, fructose - lysine is almost completely excreted in the urine.

Table 3. Ileal and faecal digestibilities of lysine in fishmeals heated to different temperatures (Wiseman, Jagger, Cole and Haresign, 1991)

Tablica 3. Ilealna i fekalna probavljivost lizina u ribljem brašnu zagrijanom na razne temperature (Wiseman, Jagger, Cole i Haresign, 1991)

	Ileal digestibility of lysine - Ilealna probavljivost lizina	Faecal digestibility of lysine - Fekalna probavljivost lizina
Fishmeal untreated Netretirano riblje brašno	0.92	0.99
3h @ 130° 3 sata na 130°	0.90	0.95
1.25h @ 160° 1,25 sati na 160°	0.84	0.91

Table 4. Growth rate (g/day) of pigs fed diets containing 100g/kg fish meal where amino acid supply was formulated on the basis of ileal or faecal digestibility or total amino acid. (Wiseman, Jagger, Cole and Haresign, 1991)

Tablica 4. Stopa rasta /g/dan/ svinja hranjenih obrocima koji sadrže 100g/kg ribljeg brašna gdje je unos aminokiselina načinjen na temelju ilealne i fekalne probavljivosti ili ukupnih aminokiselina

	Fishmeal treatment - Tretiranje ribljeg brašna			
	Untreated - Netretirano	130°	160°	Mean - Prosjek
Method of formulation (amino acids) - Metoda formuliranja (aminokiseline)				
Total - Ukupno	497	473	318	429
Faecal - Fekalno	504	494	419	472
Ileal - Ilealno	466	498	406	456
Mean - Prosjek	488	490	389	

In order to take account of availability, the work of Yen et al (1986a,b), where the ideal protein was devised on the basis of the provision of at least the minimum of each essential amino acid, has been examined. These values, which in some cases have surpluses, have been converted to ileal digestible values and presented with the recommendations of Wang and Fuller (1990) (Table 5).

Availability can be considered in another sense. It has been suggested that it is necessary to feed more frequently than once per day when using high levels of pure lysine (Batterham, 1974; Batterham and O'Neill,1978). This is to ensure that the lysine is in phase, at the metabolic sites, with the other amino acids which are protein-bound. Similar results have been found at the University of Nottingham with the supplementation of pure threonine (Table 6). However, modern production techniques using ad libitum feeding are likely to result in the frequent intake of small meals, in which case such problems may not be encountered.

TOTAL SUPPLY OF AMINO ACIDS

A useful way of indicating total amino acid supply is to relate it to energy. As lysine is usually the first limiting and, thus, the reference amino acid, the supply can be expressed as g lysine/1 MJ digestible energy. Recent work at the University of Nottingham has sought to establish these requirements for highly selected modem hybrid pigs (Table 7).

Table 5. Ratios of the ileal digestible essential amino acids in the ideal protein used by Yen et al. (1986a,b) and Wang & Fuller (1990) for growing pigs

Tablica 5. Omjeri ilealno probavljivih esencijalnih aminokiselina u idealnoj bjelančevini prema primjeni Yen i sur., (1986a,b i Wang i Fuller (1990) za svinje u rastu

Amino acid Aminokiselina	Yen et al (1986a)	Yen et al (1986b)	Wang&Fuller (1990)
Lysine - Lizin	100	100	100
Methionine - Metionin	37	39	-
Methionine + cystine Metionin + cistin	52	58	60
Threonine - Treonin	64	67	66
Tryptophan - Triptofan	19	21	18.5
Isoleucine - Izoleucin	73	76	60
Leucine - Leucin	130	140	111
Phenylanine - Fenilalanin	86	95	120
Histidine - Histadin	43	46	-
Valine - Valin	90	97	75

Table 6. Influence of dietary threonine level and frequency of feeding on urinary nitrogen (g/d) (Santoma and Cole, unpublished)

Table 6. Utjecaj razine treonina u obroku I učestalost hranidbe na urinarni dušik (g/d) (Santoma i Cole, neobjavljeno)

Threonine (% of diet) Treonin (% obroka)	Feeding frequency - Učestalost hranjenja	
	Once daily Jedanput dnevno	Twice daily Dvaput dnevno
0.55	17.68	16.34
0.60	17.87	16.08
0.65	17.29	15.45

The 3 major determinants of protein/amino acid requirements are liveweight, genotype and sex (Table 8). Those designated "hybrid" in Table 8 are extremely advanced genotypes and it is unlikely that commercial producers would have access to these. It is very important that the genotype is correctly identified. Those designated "high" in Table 8 are likely to be those used by progressive commercial producers.

Table 7. Lysine requirements and optimum lysine/DE ratio of fast growing pigs from 15 to 150 kg live weight (Van Lunen and Cole, 1996)
Tablica 7. Potrebe za lizinom i optimalni lizin/DE omjer u svinja brzog tova od 15 do 150 kg žive vage (Van Lunen I Cole, 1996.)

Live weight Živa vaga (kg) (g/MJ)	PDR[1] (g/d)	Maintenance[2] Uzdržna (g lysine/d)	Production[3] Proizvodnja (g lysine/d)	Total - Ukupno (g lysine/d)	Optimum Optimalno lysine/DE
20	114	0.43	14.25	14.68	1.20
30	137	0.58	17.13	17.70	1.15
40	157	0.72	19.63	20.34	1.10
50	172	0.85	21.50	22.35	1.05
60	182	0.97	22.75	23.72	1.00
70	186	1.09	23.25	24.34	0.95
80	186	1.20	23.25	24.45	0.90
90	182	1.31	22.75	24.06	0.85
100	174	1.42	21.75	23.17	0.80
110	164	1.53	20.50	22.03	
120	152	1.63	19.00	20.63	
130	140	1.73	17.50	19.23	
140	127	1.83	15.88	17.71	
150	114	1.93	14.25	16.18	

[1] PDR: protein deposition rate – stupanj odlaganja bjelančevina
[2] 36 mg/kg W^{075}, true digestibility 80% - 36 mg/kg W^{075}, stvarna probavljivost 80%
[3] 70 mg/g lysine in PDR, true digestibility of 80 %, absorption efficiency 70 % - 70 mg/g lizina u PDR, stvarna probavljivost 80%, učinkovitost apsorpcoje 70%

Table 8. Optimum lysine/digestible energy (g/MJ/DE) ratios in the diets of growing pigs
Tablica 8. Optimalni omjeri lizin/probavljive energije (g/MJ/DE) u obrocima svinja u rastu

Van Lunen and Cole (1996)

Maximum PDR (g/d) Maksimalni PDR (g/d)	Sex - Spol	Unimproved Bez poboljšanja	Average Prosječni	High Visoki	Hybrid Hibrid
Liveweight (kg) - Žive vage (kg)		100	125	150	175
Up to 25 - Do 25	Castrate - Kastrat	0.78	0.85	0.88	1.20
	Gilt - Nazimica	0.80	0.85	0.90	1.20
	Boar - Nerast	0.83	0.88	0.93	1.20
25 to 55 - 25 do 55	Castrate - Kastrat	0.73	0.78	0.83	1.10
	Gilt - Nazimice	0.75	0.80	0.85	1.10
	Boar - Nerast	0.78	0.83	0.88	1.10
55 to 90 restricted fed Ograničeno hranjenje	Castrate - Kastrat	0.55	0.55	-	-
	Gilt - Nazimice	0.65	0.65	-	-
	Boar - Nerast	0.70	0.70	-	-
55 do 90 fed ad libitum Hranjenje ad libitum	Castrate - Kastrat	-	0.58	0.63	0.95
	Gilt - Nazimice	-	0.60	0.65	0.95
	Boar - Nerast	-	0.63	0.68	0.95

SAFE MEAT PRODUCTION-ANTIBIOTICS AND GROWTH PROMOTERS

The reliance on growth promoters and antibiotics has been particularly common in pig production. Legislation and pressure from supermarkets/consumers has resulted in a search for alternatives.

One of the most vulnerable stages for the pig is the immediate post-weaning period and consequently this has been one of the times of greatest reliance on antibiotics. Thus, this can act as a suitable example of the search for antibiotic alternatives.

It is unlikely that a single material will replace an antibiotic. It is more likely that our thinking will go back to basic principles and that a structured approach will be taken to the diet at this stage.

THE PIGLET AT WEANING

Whatever the age at weaning, the two or three weeks after weaning are one of the most difficult periods in the piglet's life. It can be characterised by growth check, diarrhoea and mortality. The sudden transition from milk to a dry diet is a shock to the digestive system. Feed intake in the first week is usually low and this is associated with a depression in villus height. In the period between five and fifteen days post weaning there is often a very high excretion of haemolytic E. coli. Added to this is the active development of the digestive enzyme system. The earlier weaning takes place, the more immature is the digestive system. The situation in recent years has been made more difficult by the move away from the use of antibiotics.

One of the most noticeable changes after weaning is the big reduction in lactic acid content of the gut. It has been known for many years that of the organic acids used in the drinking water, lactic acid is particularly effective in controlling haemolytic E. coli and improving growth performance. While acids generally reduce pH, it is believed that lactic acid has other specific effects. Similarly, it is well established that dairy products in the diet at this stage are beneficial. For example, it is often recommended that a minimum of 8% dried whey is important in the diet of pigs post-weaning. Thus, some of the important aspects of the post weaning diet will be:

- Inclusion of a milk product
- Acidification
- Materials to establish a beneficial gut microflora

Feed intake is low in the immediate post-weaning period. It is particularly so in the first few days. For example, food and water intake on the first day can be of the order of 0.026kg and 0.361/piglet (Fowler and Gill, 1989). This means that the drinking water is a particularly good vehicle to supply additives. This is further reinforced by the observation that sick piglets will often drink when they do not eat. Recently, it has been suggested that elevated water intake in the post weaning pig can be a signal that the symptoms of diarrhoea will be seen in the faeces within 24 hours (National Committee for Pig Breeding Health and Nutrition, 1998).

The use of organic acids together with lactic acid bacteria presents an approach which gives the benefits of direct reduction of pH and, at the same time, provides a continuous supply of lactic acid. There are a number of benefits of such materials both in-feed or in the drinking water of pigs after weaning. Results have been particularly impressive when such materials are given with a good source of lactose.

In the absence of antibiotics the establishment of a satisfactory gut microflora can be achieved in a number of ways, which include:

- Probiotics to achieve a population of beneficial bacteria by competitive exclusion (Figure 2)
- The use of dietary oligosaccharides to bind with harmful bacteria.
- The use of biopeptides for multiple functions (see earlier)

It is interesting that different bacteria attach preferentially in different organs. For example, while some settle in the digestive tract, others may prefer the urinary tract or other organs. Consequently, cell recognition is important to

bacteria. It is suggested that carbohydrates (sugars) are the primary markers for cell recognition with all cells carrying a sugar coat. The micro-organism has glycoproteins (lectins/fimbriae) on the surface of cells, which can recognise and combine rapidly, selectively and reversibly with the sugar (oligosaccharide) of the gut wall (Figure 2).

Recently there has been interest in using this lectin/carbohydrate relationship in a probiotic way. Oligosaccharides particularly are being used. For example, it is thought that encouragement of bifidobacteria by the Oligosaccharides of milk gives the suckling animal a measure of good health. After weaning there is a period of vulnerability. Oligosaccharides, for example, mannan Oligosaccharides (MOS), have been used in the diets of weaned pigs and poultry and are available in health food shops. Harmful bacteria must first of all attach to the gut wall to cause disease. If they attach to an oligosaccharide, not part of the gut wall, they pass out with the digesta (Figure 3) and do not cause a problem.

Mannan oligosaccharides, for example Bio-Mos, can be used as an alternative or complementary approach to the use of probiotics. Unlike probiotics these are robust chemicals which withstand heat, metals and antibiotics. They function as free floating receptor sites in the gut and harmful bacteria often bind to them instead of the gut wall. In addition, they are known to stimulate the immune system.

To the nutritionist, Bio-Mos offers a route to provide additional protection against enteric pathogens and to enhance the animal's ability to defend itself against different stressors. However, the true value of changes in immunoligical parameters to the pigs health and performance can only be evaluated in performance trials.

Figure 2. **(A) represents a mixed population of bacteria with substantial attachment of pathogenic bacteria. (B) shows competitive exclusion of pathogens due to preferential attachment of non-pathogens. It should be noted that the recognition of receptor sites (carbohydrates) by the bacterial fimbrae (lectins) is very specific to different types of organisms (Ewing and Cole, 1994).**

Slika 2. **(A) predstavlja mješovitu populaciju bakterija sa znatnim dodatkom patogenih bakterija. (B) prikazuje rivalsko isključenje patogena zbog preferencijalne prisutnosti nepatogena. Valja primijetiti da je prepoznavanje mjesta receptora (ugljikohidrata) od bakterijskih fimbrija (lektina) vrlo specifično za razne tipove organizama (Ewing i Cole, 1994.).**

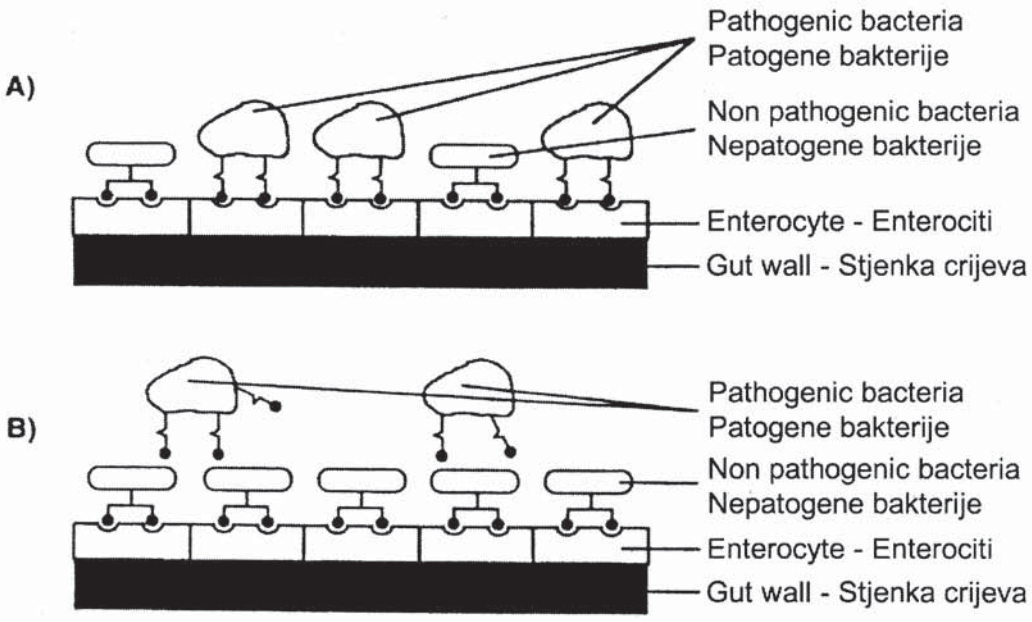


Figure 3. **The lectin-carbohydrate combination is specific to a particular organism. However, if the same carbohydrate (e.g. an oligosaccharide) is provided in the diet, harmful bacteria can be encouraged to attach to these and they do not adhere to the gut-wall but are excreted without producing toxins (Ewing and Cole, 1994).**

Slika 3. **Kombinacija lektina i ugljikohidrata je specifična za određeni organizam. Međutim, ako se isti ugljikohidrat (npr. oligosaharid) daje u obroku štetne se bakterije mogu izazvati da im se pridruže i one ne ostaju uz stijenke crijeva nego se izlučuju bez stvaranja toksina (Ewing i Cole, 1994.).**

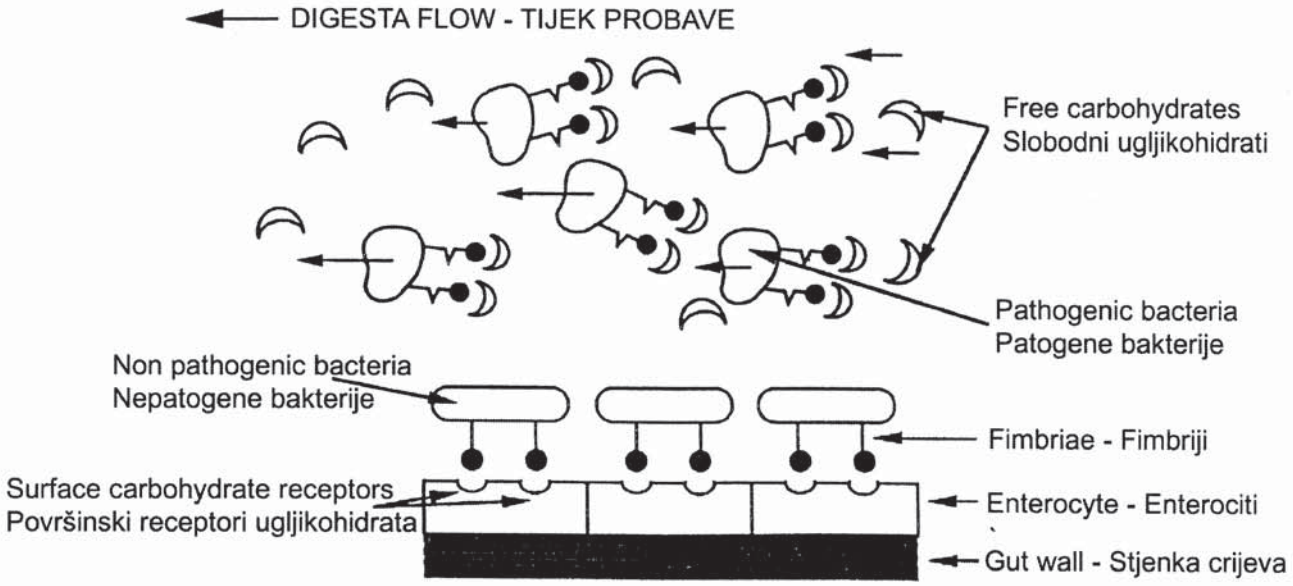


Table 8. **A comparison of BioMos and Olaquindox fed to young pigs from 9 kg liveweight (Bolduan, Schuldt and Hackl, 1997)**

Tablica 8. **Usporedba Biomosa i Olaquindoxa davanih mladim svinjama od 9 kg žive vage (Bolduan, Schuldt i Hackl, 1997).**

Feed additive - Dodatak hrani	Control	0.2% BioMos	50ppm Olaquindox Feed
Feed intake (g/day) - Unos hrane (g/dan)	901(100%)	951 (106%)	927 (103%)
Growth rate (g/day)- Stopa rasta (g/dan)	428 (100%)	469 (110%)	452 (106%)
FCR	2.18 (100%)	2.10 (96%)	2.11 (97%)

All diets were offered with 0.65% formic acid - Svi su obroci davani s 0.65% formične kiseline

Some of the most interesting work on this subject comes from the University of Rostock (Bolduan, 1999). As a first consideration, it is suggested that the appropriate acidification is adopted (e.g. up to 0.65% formic acid). Initially he showed that Bio-Mos (2kg/tonne) gave a better performance than Olaquindox (50ppm) when offered with 0.65% formic acid. BioMos gave a 10% improvement over control in growth rate and Olaquindox a 6% improvement (Table 8).

The key period for action in the post weaning pig is when the problem is at its worst (Figure 13). This needs to be considered against the background of the low feed intake in the post weaning pig. It is particularly important that intakes are high in the first two weeks. However, they are

generally low with, for example, little eaten on the first day or so. To cope with this, the Rostock group suggested that instead of a constant inclusion rate of 2 kg BioMos/tonne, it would be more effective to have a step-down inclusion with higher levels at the start. They proposed levels of 6, 3, 1 and Okg/tonne in weeks 1, 2, 3 and 4 respectively. This would result, typically, in BioMos intakes being a good match to the E. coli excretion described earlier. The step-down technique gave 11% better performance than control pigs and 7% improvement over constant BioMos. Clearly, the adoption of a system to match the daily intake of BioMos to the problem has to be reconciled with the practical feeding system and range of diets.

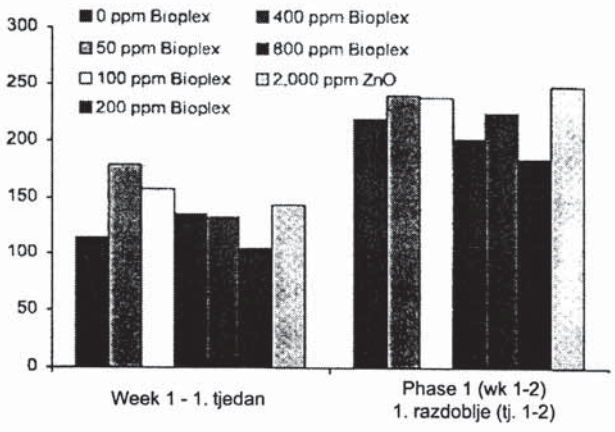
ZINC

Zinc oxide is used widely to improve gut health in the post weaning pig.

The recent work of Carlson at the University of Missouri has compared the response of young pigs to Bioplex Zn and zinc oxide (Figure 4). She concluded that 100-200pm Zn from Bioplex Zn was as effective as 2000 ppm Zn from ZnO. She believes that zinc is working at gut local level (Carlson, 2000).

Figure 4. Effect of supplemental Bioplex Zn on nursery pig growth performance during the first two weeks post-weaning.

Slika 4. Učinak dodatnog Bioplex Zn-a na rast mlade prasadi u prva dva tjedna nakon odbića.

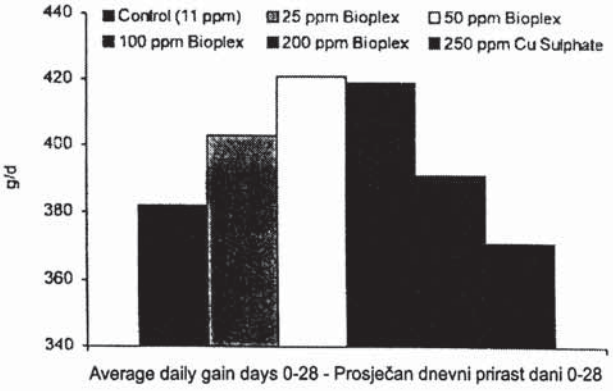


COPPER

Copper, particularly $CuSO_4$, has long been used as a growth promoter in pig diets. It's use is limited by legislation in many countries, and so there is increased interest in alternative provision. Carlson (2000) believes that copper works, as a growth promoter, after absorption. She has achieved better results with 50 ppm Cu from Bioplex Cu than 250 ppm from copper sulphate (Figure 5).

Figure 5. Effect of supplementing Bioplex Copper to nursery pigs on average daily gain.

Slika 5. Učinak dodavanja Bioplex bakra praščićima na prosječni dnevni prirast



The diet, meat and health

SELENIUM

The role of selenium in both human and animal nutrition is under active research. It is worth emphasising some of these points.

Selenium was discovered in 1817 by Jons Jakob Berzelius but it was not until 1957 that it was recognised as an essential trace mineral. In 1973, the antioxidant glutathione peroxidase was identified as the principle selenoprotein in the body. Selenoproteins have a variety of roles in the body and more than 30 have been identified in the last 10 years.

An adequate supply of Se is important in the human diet. Typical recommended daily allowances for adults are of the order 50-200 μg/d (NRC, 1980) while individual reports have been as high as 500 μg/d (Sakurai and Tsuchiya, 1975). More recently

recommended daily allowances have been suggested as 70 ug/d for men and 55 ug/d for women.

Such levels are recommended for adequate nutrition of healthy individuals and many countries do not achieve these. A number of conditions in the human have been suggested to be responsive to Se and these include cancer, asthma, infertility, heart disease, arthritis and ageing. The work of Clark et al (1996) showing reductions of 63%, 58% and 46% of prostate, colorectal and lung cancer respectively with Se supplementation is significant.

Early work with rats had shown a reduction in tumours when the diet was supplemented with 0.5 ppm Se (Clayton and Bauman, 1949). In humans it has been suggested that the dose for cancer patients is the amount needed to restore their blood selenium levels to normal (Passwater, 1996). In individual cases this level has been reported to be as high as 2000 ug/d (Passwater, 1996).

DISTRIBUTION

The distribution of Se in the world is extremely variable. To the animal nutritionist the Se content of plants is of great interest. This is influenced by a number of factors. The first is in the nature of the plants. These have been defined as Primary, Secondary and Non-Accumulators according to their ability to accumulate Se when grown in high Se soils (Rosenfeld and Death, 1964).

Most plants contain about 10ppm Se. An example of a primary accumulator is Astragulus racemosus with a recorded Se content of 14,990 ppm (Death et al., 1937). Aster, Atriplex and Grindelia are examples of secondary accumulators and contain no more than a few hundred ppm Se. Non-accumulators normally have less than 50ppm Se when grown in seleniferous soils and include grains, grasses and many weeds.

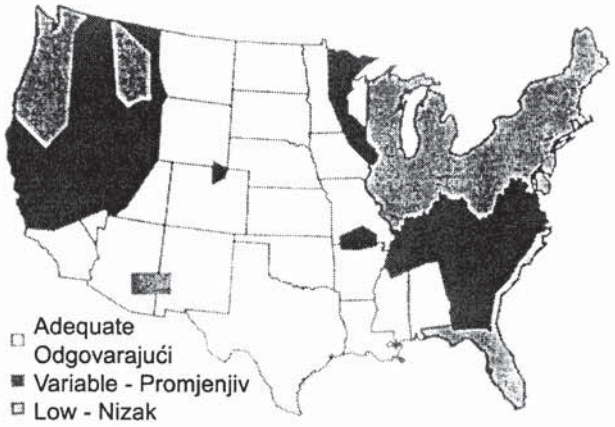
Such information has been used in farming. For example, in New Zealand Agrostis tennis (Brown Top) has been used because it accumulates 2-7 times as much Se as Trifolium repens (White Clover).

As plants obtain their Se from the soil, its status will be of importance. Soils are variable with up to 2ppm being common but reported values of up to 100ppm. In some countries Se fertilisation is practiced. Soil status must be linked to the pH of the soil and the presence or absence of other elements. In wet acid soils, a ferric-iron-selenite complex may form, when Se is poorly available to animals. In well drained alkaline soils, highly available selenates are formed.

Generally, plants contain about 50% of the Se as selenomethionine with only small amounts of inorganic Se. Se status of plants can be mapped geographically (Figure 6) and this knowledge can be used in local animal nutrition. However, some countries which have a high animal population and small land mass are importers of feedstuffs from diverse sources. In these cases there problem is greater.

Figure 6. Selenium concentrations in crops from US

Slika 6. Koncentracije selena u usjevima u SAD-u



HUMAN DIET

The potential for inadequacies in the human diet has been recognised for many years. For example, plants grown in eastern and western parts of the US are often Se deficient. The Se status in Europe is variable but the Scandinavian countries are particularly deficient. Many parts of Asia are also markedly deficient.

These deficiencies in the human diet have stimulated governments to take action to alleviate the problem. One such initiative has been to focus

on increasing Se, not only in crops, but also in meat, milk and eggs. An example of this is the investment by Sweden into research in this area. A practical result was Pehrson's work at the Veterinary Institute of Skara, into the increase of Se in cows' milk by the use of dietary selenium yeast. This has been paralleled by increasing Se in pig meat and sows' milk by Mahan at Ohio State University and poultry by Cantor in Kentucky.

The influences of dietary Se on carcase and meat quality in pigs have been well established. The ability of selenium yeast to increase Se content of the muscle of growing pigs has been shown to be particularly effective compared with sodium selenite (Figure 7).

Figure 7. **Effect of selenium source (selenium yeast as Sel-Plex vs sodium selenite) and level on loin selenium content in grower pigs (Mahan, 1999)**

Slika 7. **Učinak izvora i razine selena (selenski kvasac kao Sel-Plex prema natrijevom selenitu) na sadržaj selena u slabinama u svinja u tovu.**

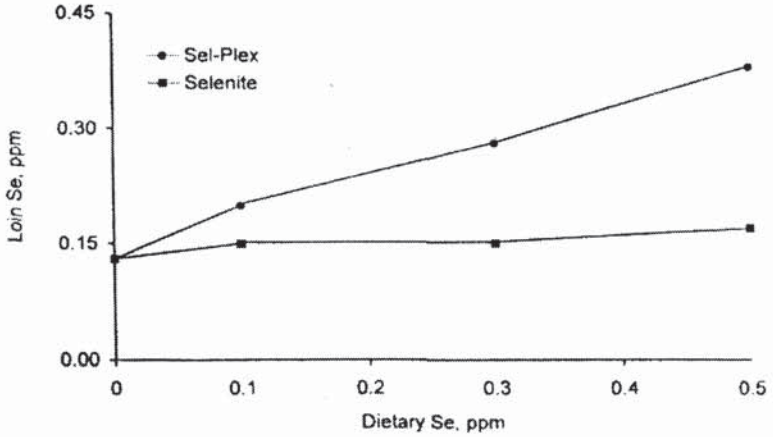
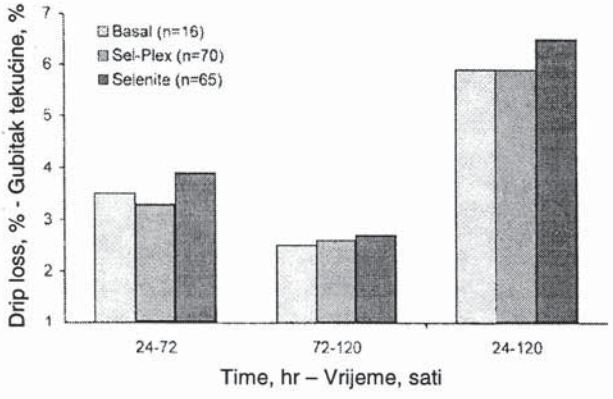


Figure 8. **Effect of selenium (Sel-Plex /selenium yeast/ or sodium selenite) on drip loss (pork loin) (Loins collected after a 24 hr chill) (Mahan, 1999)**

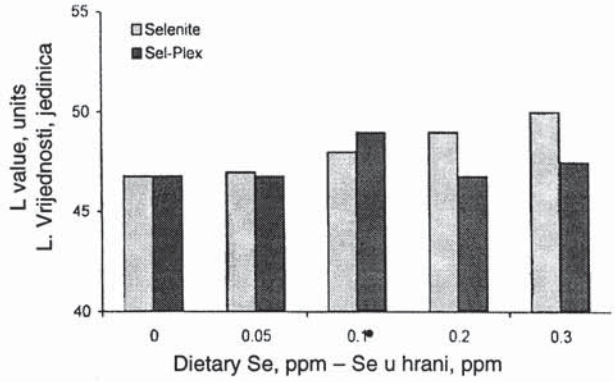
Slika 8. **Učinak selena (Sel-Plex /selenski kvasac/ ili natrijevog selenita) na gubitak tekućine (svinjske slabine) nakon 24 sata hlađenja (Mahan, 1999)**



The meat from such pigs (receiving dietary selenium yeast) had lower drip loss than those fed sodium selenite (Figure 8). The interpretation has been that using selenium yeast does not affect drip loss but that inorganic selenium increased it. The feeding of selenium yeast also results in darker pork than sodium selenite (Figure 8)

Figure 9. **Effect of selenium source (Sel-Plex (selenium yeast) or sodium selenite) on pork colour (Hunter L value) (Loins collected afler a 24 hr chill) (Mahan et al., 1999)**

Slika 9. **Učinak izvora selena /Sel-Plex (selenski kvasac) ili natrijev selenit/ na boju svinjetine (Hunter L. vrijednost). Slabine uzete nakon 24- sata hlađenja/.**



SELENPORK

Initiatves based on such knowledge are perhaps not surprising but the development by a nongovernment private enterprise scheme in Korea shows a novel approach. Firstly, pig meat is

branded. It was given the name SelenPork to identify it from other meats. This in itself is quite unusual as meat is usually bought by species, cut, appearance and price.

To qualify for the name SelenPork, pigs have to be produced in a particular way.

- a specified hybrid pig must be used
- a specified diet (Soma feed) must be fed from 60-100kg liveweight and this contains 0.5ppm Se from selenium yeast

Trials to examine the influence of selenium yeast (Sel-Plex) in these production systems have been reported (Table 9). It was concluded that 0.5 ppm Se from selenium yeast (Sel-Plex) gave the most economic accumulation of Se in pork. More recently, the same worker (Han, personal communication) has obtained values of 0.22 ppm Se in pork from pigs not given selenium yeast and 4.15 ppm for the supplemented treatment. He has concluded that SelenPork contains about 20 times as much Se as normal pork.

Table 9. Selenium content (ppm) of SelenPork (ham and loin) (Han, personal communication)
Tablica 9. Sadržaj selena u Selen svinjetini (šunka i slabine) (Han, osobna komunikacija)

	Trial 1 - Pokus 1 (Korea)	Trial 2 - Pokus 2 (Ohio State University)
Some feed* - Soma krmivo	0.29	0.22
Soma feed* + 0.4ppm Se yeast (Sel-Plex) Soma krmivo + 0.4ppm Se yeast (Sel-Plex)	5.06	4.87
Soma feed* + 0.8ppm Se yeast (Sel-Plex) Soma krmivo + 0.8ppm Se yeast (Sel-Plex)	2.72	4.47

* Contains 0.1 ppm Se from basal ingredients and 0.15 from the mineral prernix - Sadrži 0.1ppm Se iz osnovnih sastojaka i 0.15 iz mineralnog premiksa

The claims for the meat resulting from such production systems using selenium yeast are:

- Tender and chewy
- Good colour
- Low fat
- Low drip loss
- Reduced pig odour

The marketing of SelenPork is strictly controlled, it may only be sold through authorised butchers and restaurants. These outlets sell Selen-Pork exclusively and no other meats. In Korea this is co-ordinated by pig co-operatives who sell to the authorised outlets on behalf of their pig farmer members. They are also responsible for co-ordinating the specified pig and pig feed requirements of their members.

Already there are more than 60 outlets widely spread across Korea (Figure 10), all administered through co-ops. These co-op outlets are jointly owned with the farmer being a shareholder.

Figure 10. Distribution of co-ops selling SelenPork in the Republic of Korea
Slika 10. Rasprostranjenost zadruga koje prodaju Selen svinjetinu u Republici Koreji.

Such production systems are profitable. At current prices it has been calculated that a US$3.5 investment will yield a return of US$11.4 to the farmer.

The restaurants are typically Korean but the decor is unusual. The walls are hung with health information, trial results and other information about selenium. This is far removed from the entertainment environment of many western restaurants. They seem to be adopting a role parallel to that of health food shops.

SelenPork is cooked on skewers of about 200-250g meat and it is calculated that each will provide about 50 μg Se thus, making a substantial contribution to daily requirements. It should be emphasised that the colour and organoleptic properties of the meat appear excellent. It has a strong red colour and is tender with a pleasant juiciness and flavour.

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SAŽETAK

Kakvoća mesa ima mnogo aspekata, a sa stajališta nutricionista može se smatrati kao:

1. Relativan omjer tkiva. Na primjer, masno/mršavo. Ovo uvelike utječe na izgled mesa.

2. Organoleptička svojstva. Na primjer, za potročača su važni okus i miris.

3. Sigurnost. Prema ispitivanju potrošača sigurnost je, bez razlike, najvažnija. Neprestano se postavljaju pitanja o reziduima u mesu i dodacima u hranidbi.

4. Učinci na poboljšanje zdravlja. Današnja potrošačka javnost vrlo je dobro informirana o dijetalnim i drugim čimbenicima što mogu pozitivno djelovati na zdravlje.

Ovo je, očito, važno pitanje pa će se dati nekoliko izabranih primjera. U postizanju ciljeva kakvoće važno je da je povoljno za farmera.