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THE EVALUATION AND STANDARDISATION OF PIG RATIONS UNDER SOUTH AFRICAN CONDITIONS: 2. THE INFLUENCE OF FEEDING PROTEIN AND ENERGY AT DIFFERENT LEVELS AND RATIOS TO BACONERS

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OPSOMMING: DIE EVALUERING EN STANDAARDISERING VAN VARKRANTSOENE ONDER SUID-AFRIKAANSE TOESTANDE: 2. DIE INVLOED VAN VERSKILLENDE PEILE EN VERHOUDINGS VAN PROTEÏEN EN ENERGIE IN DIE RANTSOEN VAN SPEKVARKE

'n Totaal van 224 varke is in twee proewe gebruik om die effek van twee isokaloriese rantsoene met 16,4 en 11,7% ru-proteïen op die groeitempo, karkasmates en die karkassamestelling van spekvarke te ondersoek. HP varke het deurgaans vrye toegang tot 'n 16,4% rantsoen gehad, terwyl LP varke *ad lib.* gevoer is op 'n 11,7% rantsoen. Varke in die HP-HP en HP-LP groepe is *ad lib.* gevoer op die 16,4% rantsoen tot 'n massa van 45 kg. waarna 'n daaglikse maksimum van 2,27 kg van die 16,4% rantsoen aan HP-HP varke gevoer is, terwyl 'n ekwivalente hoeveelheid van die 11,4% rantsoen aan HP-LP varke gevoer is. Die liggaamsmassa van HP varke het betekenisvol vinniger as HP-LP varke toegeneem, terwyl die verskil tussen die HP en HP-HP groepe net nie betekenisvol was nie. Burge het betekenisvol vinniger as soggies gegroei. LP varke het betekenisvol meer rugspek as HP varke gehad en hoogs betekenisvol meer as HP-HP en HP-LP varke, terwyl die HP-HP groep betekenisvol minder rugspek as die HP groep gehad het. Die behandelingseffekte op C + K spekmate was statisties identies met dié van die rugspekmates uitgesonderd die verskil tussen die HP en HP-HP groepe wat nie betekenisvol was nie. Soggies het hoogs betekenisvol minder rugspek en C + K vet as burge gehad. Die oogspieroppervlaktes van HP varke was hoogs betekenisvol groter as dié van HP-LP varke en betekenisvol groter as die oogspierareas van LP varke. Soggies het hoogs betekenisvol groter oorspiere as burge gehad. LP varke het hoogs betekenisvol meer karkasvet (chemies bepaal) as enige van die ander drie groepe gehad terwyl die soggies hoogs betekenisvol minder vet as burge gehad het. LP varke het hoogs betekenisvol minder karkasproteïen as die ander drie groepe gehad terwyl die proefsoggies hoogs betekenisvol meer proteïne as burgies in hul karkasse gehad het. Varke in die eerste proef gebruik, het gemiddeld 25,5% meer rugspek en 27,6% meer C + K vet as die varke in die tweede proef gebruik gehad, wat die genetiese variasie wat daar bestaan tussen varke van dieselfde ras om vet neer te lê beklemtoon.

SUMMARY

A total of 224 pigs were used in two experiments to study the effect of two isocaloric diets containing 16,4 or 11,7% crude-protein on rate of gain, feed conversion efficiency, carcass characteristics and carcass composition of baconers, fed *ad libitum* throughout the experimental period or restricted during the final period of growth. High protein (HP) pigs had free access to a 16,4% protein diet throughout the experiment, while Low protein (LP) pigs were *ad lib.* fed on the 11,7% diet. HP-HP and HP-LP pigs were fullfed on the 16,4%diet to 45 kg live mass, whereafter a daily maximum of 2,27 kg of the 16,4% diet was fed to HP-HP pigs and a like amount of the 11,7% diet fed to HP-LP pigs. HP pigs gained significantly faster than HP-LP pigs, while the difference between HP and HP-HP approahced significance. Barrows gained significantly faster than gilts. LP pigs had significantly more backfat than HP pigs and highly significantly more backfat than HP-HP and HP-LP pigs while HP-HP resulted in a significant reduction in backfat when compared with HP. Statistically, treatment effects on C + K measurements were identical to the backfat measures except that the difference between the HP and HP-HP groups was non-significant. Gilt carcasses had highly significantly less back and C + K fat than barrow carcasses. The eye-muscle areas of HP pigs were highly significantly larger than those of HP-LP pigs and significantly bigger than the muscle areas of LP pigs. Gilts had highly significantly larger muscle areas than barrows. LP pigs had highly significantly more carcass fat (chemically determined) than pigs in the other three treatments, while gilts had highly significantly less fat than barrows. LP pigs had highly significantly less carcass protein than pigs in the other three treatments, while gilts had highly significantly more carcass protein than barrows. Pigs used in the first trial had on average 25,5% more backfat and 27,6% more C + K fat than pigs used in the second experiment, thus emphasizing the genetic variation in ability to lay down fat existing between pigs of the same breed.

Rate of gain, feed conversion efficiency and carcass composition of the bacon pig is influenced to a great extent by its intake of dietary protein and energy. A great deal of attention has been given in foreign countries to protein and energy intake and the interrelationships between these two dietary constituents and the efficiency of bacon production as measured by the rate of gain, feed conversion efficiency and carcass characteristics of the baconer produced (Costain & Morgan, 1961; Wagner, Clark, Hays & Speer, 1963; Robinson & Lewis, 1964; Robinson, Morgan & Lewis, 1964; Clausen, 1965; Wallace, Palmer, Carpenter & Combs, 1966; Young, Ashton, Forshaw & Ingram, 1968; Blair, Dent, English & Raeburn, 1969a; Davies & Lucas, 1970; Lucas & Miles, 1970; Lawrence, 1971). Thusfar, work in South Africa has been confined to protein requirements only. In determining the minimum level of protein required in the diet of pigs fed from weaning to bacon mass Pieterse & Verbeek (1959) and Pieterse & Penzhorn (1960) fed their experimental animals a controlled amount of feed, 20 to 40%

Table 1

*Composition of experimental rations on an air-dry basis**

Ration		High protein (HP)	Low Protein (LP)
Yellow maize meal,	kg	73	75
Lucerne meal,	kg	10	10
Wheaten bran,	kg	5	11
Fish meal,	kg	12	4
Salt,	kg	1	1
Bone meal,	kg	1	1
Minerals & Vitamins**,	kg	0,15	0,15
Digestible energy content,	MJ/kg	14,35	13,96
Metabolizable energy content,	MJ/kg	13,71	13,48
Crude Protein content,	%	16,35	11,74
Amino acids as a % of ration			
Lysine		0,88	0,50
Histidine		0,50	0,39
Threonine		0,59	0,39
Valine		0,94	0,59
Methionine		0,51	0,22
Isoleucine		0,75	0,40
Leucine		1,43	0,96
Tyrosine		0,46	0,28
Phenylalanine		0,65	0,47
Arginine		0,86	0,67

* The HP ration contained 10,89% moisture and the LP ration 10,78%.

** A commercial Vitamin, Mineral mixture was used.

in excess of the quantity presently recommended, (Kemm Pieterse, Griessel & Mammes, 1971) during the finishing phase.

Due to consumer demand for leaner pork and bacon, grading regulations are altered from time to time to force the production of leaner pigs. Consequently the energy requirements as well as the energy: protein ratio in the diets fed to bacon pigs need adjustment if carcasses that will meet consumer demand are to be produced. The experiments described in this paper were designed to study the effect of two isocaloric diets differing in protein content on rate of gain, feed conversion efficiency, carcass characteristics and carcass composition of baconers, fed *ad libitum* throughout the experimental period or restricted during the finishing period of growth.

Procedure

Trial 1: Forty weanling pigs, on average 63,1 days old, were divided according to sex, live mass and litter origin into four comparable groups of 10 each and subjected to four nutritional treatments. Two diets compounded as in Table 1 were used. Diet analyses were made according to the methods used by Kemm *et al.* (1971).

Pigs were fed a 16,4% protein diet *ad lib* throughout the experiment (HP), an 11,7 diet throughout the experiment (LP) or the HP diet to 45 kg followed by either the HP or the LP diet at 2,27 kg daily to 90 kg. Individual pigs were slaughtered the day subsequent to attaining a live mass of 90 ± 2,5 kg. The carcasses were chilled for 48 hours and then weighed to obtain the cold carcass mass. Carcasses were then suspended by the hind legs, the head removed and split medially down the back so that the appropriate carcass measurements could be made according to the methods described by Kemm *et al.* (1971).

The right side of each carcass minus the head (removed at the atlanto-occipital joint) was ground, freeze dried and chemically analysed for moisture, fat, protein and ash as described by Kemm *et al.* (1971). The energy content of the ground freeze dried samples was then determined using an adiabatic bomb calorimeter. All the results were statistically analyzed by the analysis of variance technique.

Trial 2: Twenty-four litters from eight purebred Landrace sows served by the same Landrace boar and yielding a total of 184 piglets were randomly allotted at weaning (when 56 days old) as intact litters to four groups, irrespective of litter size or number, as indicated in Table 2, and subjected to the same treatments imposed in the first trial. As there was a frequent occurrence of seasonal overlapping and an even spread of litters throughout the year, seasonal effects were not taken into account.

Table 2

Trial 2: Allotment of litters to the various Treatments

Treatment	HP		LP		HP-HP		HP-LP	
	Barrows	Gilts	Barrows	Gilts	Barrows	Gilts	Barrows	Gilts
Litter from Sow No.								
53	2	4	3	4	1	7	3	4
53	5	3	–	–	–	–	–	–
74	4	5	4	6	6	4	7	3
112	3	4	3	3	–	–	–	–
113	4	3	–	–	5	2	3	4
22	2	6	–	–	–	–	–	–
114	–	–	5	5	4	1	7	1
110	–	–	1	7	4	4	5	4
110	–	–	3	3	4	3	2	4

The experimental procedures followed were identical to those employed in the first trial except that chemical analyses of the carcasses were not done. The results were analysed according to the standard method of analyses for unbalanced data as described by Harvey (1960).

Results

Trial 1

Treatment and sex effects on live mass gain, feed conversion efficiency, carcass characteristics and carcass dry matter (DM) composition for the pigs in Trial 1 are summarized in Table 3.

live mass than LP pigs. Restricting intake of the HP diet (HP-HP) to 2,27 kg a day from a live mass of 45 kg onwards improved feed utilization efficiency to 3,22, while feeding a restricted amount of the LP diet (HP-LP) also improved feed utilization but to a lesser degree (3,34). As the pigs were group-fed sex effects as well as the statistical significance of the data could not be determined.

Table 3

Trial 1: Average live mass gain, feed utilization, carcass characteristics and carcass composition

Treatment	HP	LP	HP–HP	HP–LP	LSD P =0,05	LSD P =0,01	Sex Effects Barrows	Sex Effects Gilts
Initial mass, kg	17,9	17,1	17,5	17,1			17,1	17,7
Slaughter mass, kg	90,9	91,2	90,5	90,1			90,6	90,8
Daily gain, kg	0,67	0,65	0,62	0,61	0,05		0,66*	0,62
Feed utilization, kg feed/kg gain	3,43	3,47	3,22	3,34				
Carcass characteristics:								
Dressing percentage	78,9	78,9	78,9	77,6			79,1	78,1
Carcass length, mm	841,0	830,0	834,0	837,0			831,0	840,0
Backfat thickness, mm	37,1	40,5	33,8	35,2	2,6	3,5	39,3**	34,0
C + K measurements, mm	58,9	66,9	54,1	58,6	6,1	8,2	64,5**	54,8
Eye muscle area, cm^2	34,7	31,9	32,7	30,8	2,71	3,68	30,5**	34,5
Carcass composition:								
Fat in carcass DM, %	66,6	70,6	66,3	67,3	2,36	3,20	69,7**	65,7
Protein in carcass DM, %	28,0	24,4	28,5	27,5	1,87	2,53	25,5**	28,8
Ash in carcass DM, %	5,7	5,0	6,1	5,5	0,40	0,64	5,2**	6,0

*Statistically significant at $P < 0,05$
**Statistically significant at $P < 0,01$

Live mass gain

The data presented reveal that the protein content of the diet, the amount of feed fed after the pig attains a live mass of 45 kg as well as the sex of the pig influenced live mass gain. Pigs fed an unlimited quantity of the HP diet throughout the experiment gained significantly ($P < 0,05$) faster than those fed a restricted amount of the LP diet (HP-LP) after 45 kg live mass, while the difference between HP and HP-HP groups approached significance. Barrows gained significantly ($P < 0,05$) faster than gilts, with no treatment x sex interaction on rate of gain.

Feed utilization

Both the protein content of the diet and the quantity of feed fed influenced the amount of feed required to produce a kg of live mass gain. Protein content of the diet had very little effect on feed utilization when the diet was fullfed throughout the experimental period in that HP pigs required only 0,04 kg less feed to gain a kg in

Carcass characteristics

1. *Dressing percentage*

There were no significant treatment, or sex, effects on dressing percentage.

2. *Carcass length*

As indicated in Table 3, carcass length was not significantly influenced by either dietary treatment or sex.

3. *Backfat thickness and C + K measurement*

Both carcass backfat thickness and the C + K fat measurements were significantly affected by level of feed intake during the final period, protein content of the diet and sex of the animal. Pigs fullfed the LP diet throughout the experiment had significantly ($P < 0,05$) more backfat than pigs fullfed the HP diet and highly significantly ($P < 0,01$) more backfat than pigs fed limited quantities of the (HP-HP) or LP (HP-LP) diets during the final

Table 4

Trial 2: Effect of Treatment on daily gain and carcass characteristics

	Constant Estimates			
Treatment	HP	LP	HP-HP	HP-LP
Daily gain**	0,05	-0,001	-0,02	-0,03
Dressing percentage*	0,54	0,02	0,19	-0,75
Carcass length	-0,02	-0,04	0,14	0,13
Backfat thickness**	-0,03	0,04	-0,04	-0,11
C + K fat measurement**	0,15	0,47	-0,36	-0,26
Eye muscle area**	-0,73	-2,39	2,91	1,21

* Statistically significant at P < 0,05

**Statistically significant at P <0,05

between the two sexes.

4. *Eye muscle area*

Full-feeding the HP diet throughout the trial period resulted in eye muscles that were highly significantly (P < 0,01) larger than those of pigs fed a restricted amount of the LP diet (HP-LP) and significantly (P < 0,05) greater than muscle areas of LP pigs. The differences between the LP, HP-HP and HP-LP groups were small and statistically non-significant. Gilts yielded carcasses that had significantly larger (P < 0,01) loin-eye areas (34,5 vs 30,5 cm^2) than those of the castrates.

Carcass composition

The treatment effects on the chemically determined fat content of the carcass were, as can be seen in Table 3, very similar to the effects on backfat and C + K measurements. Pigs fed an unrestricted amount of the LP diet throughout the trial period had between 3,3 and 4,3% more fat in their carcasses than pigs in the other three treatment groups. Statistically, the occurring differences between the LP and the other three groups are highly significant (P < 0,01), with small insignificant differences between HP, HP-HP and HP-LP groups. Gilts had significantly (P < 0,01) less carcass fat than barrows.

The data on the protein content of the carcasses is, as expected, an exact reverse of the fat data, in that LP pigs had significantly (P < 0,01) less carcass protein than pigs in the other three groups, with small insignificant differences occurring between HP, HP-HP and HP-LP groups.

Carcass ash varied between 5,0% in the LP group and 6,1% in the HP-HP group depending on the carcass protein content, so that a fairly constant ash to protein ratio of approximately 17:83 was maintained irrespective of treatment. Statistically LP carcasses had highly significantly (P < 0,01) less ash than carcasses from HP and HP-HP pigs and significantly less than HP-LP carcasses.

Table 5

Trial 2: Analysis of variance: mean squares of results for each variable

Source of variance	DF	Initial weight	Slaughter weight	Daily gain	Dressing percentage	Carcass length	Backfat thickness	C + K fat	Eye muscle area
Average	1	0,126250	7,573173	0,001808	9,616889*	10,683687*	0,606968**	0,012134	7,022384
Treatment	3	13,028757	1,165380	0,02004**	7,173107*	0,330512	0,418582**	3,212339**	0,617398**
Sow	7	3,133635	5,028390	0,002017	3,304695	3,215637	0,223215**	0,760117**	0,231904**
Sex	1	22,750890	10,500509	0,052617**	0,124979	28,084819	3,456593**	33,986593**	6,790600**
Litter size	3	7,087764	18,552801*	0,002588	1,538769	0,796311*	0,296311*	0,180713	0,077859
Treatment x Sex	3	9,27489	1,099544	0,002452	5,786049	1,250210	0,074001	0,472081	0,105338
Treatment x Litter size	9	8,143267	5,335527	0,009795*	1,509084	2,835806	0,115577	0,603090	0,14615
Sow x Sex	7	13,299362	8,044950	0,000816	3,395044	1,803858	0,089755	0,643907	0,100429
Sex x Litter size	3	18,405204	5,695284	0,002194	1,608991	3,625838	0,099631	0,034240	0,016377
Total reduction	37	14,763385*	5,284101	0,142900	3,382435*	5,592640**	0,355196**	2,516312**	0,537543**
Error	147	8,184589	5,157675	0,003922	2,313468	2,313468	0,077059	0,363173	0,083407

DF = degrees of freedom

* Statistically significant at P < 0,05

** Statistically significant at P < 0,01

growth period. Restriction of the HP diet (HP-HP) induced a significant (P < 0,05) reduction in backfat when compared with the HP treatments while the differences between HP and HP-LP groups as well as that between the two limited groups (HP-HP vs. HP-LP) were non-significant.

Statistically, the treatment effects on C + K measurements were identical to those obtained with backfat measurements except that the difference in C + K measurement between the HP and HP-HP groups was statistically non-significant. Gilt carcasses had significantly (P < 0,01) less backfat and C + K fat than barrows. The treatments imposed did however not have any effect on the differences

HP-HP carcasses had significantly (P<0,05) more ash than those from HP and HP-LP animals with a non-significant difference existing between these two groups.

Trial 2

In Table 4 treatment effects on daily gain and carcass characteristics are given. Table 5 summarizes the analyses of variance performed on the experimental data collected

Live mass gain

Average daily live mass gain was highly significantly (P < 0,01) influenced by the treatment imposed and by the sex of the animal. With a significant (P < 0,05) treatment x litter size interaction.

Carcass characteristics

1. *Dressing percentage.* Of the variables studied treatment alone had a significant (P < 0,05) effect on the dressing percentage.

2. *Carcass length.* Gilts had significantly (P < 0,01) longer carcasses than castrates, while treatment and other effects tested were non-significant.

3. *Backfat and C + K measurements.* Both back and C + K measurements were highly significantly (P < 0,01) influenced by the nutritional treatment to which the pigs were subjected, the sex of the pig and by the mother of the pigs used. Litter size had a significant (P < 0,05) influence on backfat thickness, but a non-significant effect on C + K fat, while the interactions tested were all non-significant.

4. *Eye muscle area.* The treatment imposed, the sex of the pig and the sow mothering the pigs used had a highly significant (P < 0,01) influence on eye muscle area, but no other significant effects due to litter size or interaction were noted.

Table 6

A comparison of daily gain and carcass characteristic means of pigs slaughtered in Trials 1 and 2

Trial	1		2	
	Mean	CV%	Mean	CV%
Initial mass, kg	17,4	6,8	18,4	16,8
Slaughter mass, kg	90,7	2,5	90,0	2,5
Daily gain, kg	0,64	8,5	0,64	12,2
Backfat thickness, mm	36,7	7,6	29,2	12,5
C + K fat, mm	59,6	11,0	46,7	19,1
Eye muscle area, cm^2	32,5	9,0	31,1	12,1

CV = Coëfficient of variation

Comparing the data obtained in the two separate trials, Table 6, it can be seen that virtually no difference existed in mean growth rate and differences of only 2,0 and 1,8 percentage units in dressing percentage and carcass length. The indices of carcass fat content namely the backfat and C + K fat measurements differed greatly in that the pigs used in the first trial had 25,5% more backfat and a C + K measurement 27,6% greater than that of the pigs used in the second trial.

Discussion

The results of our experiments relating to rate of gain and carcass characteristics were similar to those reported by other workers (Costain & Morgan, 1961; Robinson & Lewis, 1964; Robinson, Morgan & Lewis, 1964; Wallace *et al.*, 1966; Blair *et al.*, 1969 a, b; Lucas & Miles, 1970; Frape, Wilkinson, Chubb & Wolf, 1970 and Lawrence, 1971).

Rate of gain and carcass composition were influenced by protein content of the diet, the amount of feed fed during the finishing phase of growth (45 to 90 kg live mass) and the sex of the pig. Optimal rate of gain and carcass leanness (eye muscle area) was attained when the HP ration was fed *ad libitum*, while carcass protein and fat content was similar in the two groups of pigs on the HP diet (HP vs. HP-HP). Backfat and C + K measurements, were however adversely affected when pigs were fullfed the HP diet.

In comparing the data presented in Table 6 it is revealing to note the difference in back and C + K fat measurements obtained in the two experiments conducted with pigs of the same breed but of different bloodlines. The genetic capacity of the pig to lay down back and C + K fat and the sex of the pig (gilt carcasses have almost 10 mm, 15%, less C + K fat) are therefore important considerations in determining the amount of feed to be fed to baconers. As carcass grading and consumer acceptability is largely dependant on the amount of back and C + K fat present, the economic importance of these fat measures cannot be overemphasized.

The data presented in Table 6, the C + K and backfat measurements obtained by Kemm *et al.* (1971) and by Kemm, Minnaar & Bonsma (1969) indicate that if pigs of the correct genetic type are used carcass fat deposition can be limited to a desired level in both female and castrate pigs by feeding 2,27 kg per day of a diet containing about 13,7 MJ/kg ME and 16% crude protein during the period from 45 to 90 kg live mass. As the female deposits appreciably less fat than the castrate (Table 3) a suitable female carcass can be produced by *ad lib.* feeding a 16% protein diet and in so doing improve rate of gain at the same time.

The amino acid composition of the HP ration compares favourably with that accepted to be sufficient for optimum growth and carcass development of growing pigs (Robinson & Lewis, 1963; Clausen, 1965; Becker, Jensen & Harmon, 1966; ARC, 1967 and NRC, 1968).

During the growth period from 45 to 90 kg. growth and feed conversion efficiency does not appear to be improved to any great extent by increasing the protein level

above 12 or 14% when fed at a constant level of energy intake as is apparent in Table 3 and from the work of Robinson & Lewis (1964), Young *et al.* (1968) and Blair *et al.* (1969). Carcass leanness can, however, be improved by increasing the protein content to 16% or more (Robinson & Lewis, 1964; Holme, Coey & Robinson, 1965; Blair *et al.*, 1969b and Young *et al.*, 1968). The improvement in carcass leanness attained with diets containing more than 16% protein is, however, dependant on the protein quality and energy content of the diet and the amount of ration fed. Robinson & Lewis (1964) attained best performance with a 16% protein diet of 2950 kcal. DE and a lysine:energy ratio of 3500. In the present study the HP diet contained 16,35% protein, 3429 kcal DE/kg and had a lysine:energy ratio of 3896.

Further evidence of the important influence of genotype on the carcass characteristics of the baconer can be found in Table 5 in that a highly significant sow effect on back and C + K fat measurements and on eye muscle size is apparent.

In conclusion, it is felt that further research should be directed towards establishing to what extent fat deposition in *ad lib.* fed pigs can be restricted without unduly retarding livemass gain. In future work on the protein and energy nutrition of the baconer attention should also be devoted to the net efficiency whereby protein and energy is utilized by pigs, slaughtered at different masses, to establish at what mass the most efficient end product can be produced.

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