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RELATIONSHIPS AMONG SOME PHYSICAL AND CHEMICAL PARAMETERS OF FULL- VERSUS LIMITED-FED YORKSHIRE PIGS SLAUGHTERED AT DIFFERENT LIVE WEIGHTS

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Abstract: An experiment was designed using 30 Yorkshire pigs to study the influence of slaughter weight and feed restriction on carcass cut-out data and to relate these physical measurements to the chemically-determined proximate components. As slaughter weight increased from 79 to 102 kg., the percent of all lean cuts decreased significantly, while that of fat cuts and back-fat thickness increased significantly. Absolute amounts of both fat and lean cuts increased with slaughter weight. Feed restriction significantly increased most of the lean parameters studied and reduced the fat measurements. It increased percent of head and reduced the percent of offal (gastrointestinal tract minus contents, head, respiratory tract and all other internal organs). Correlations between leaf fat and empty body weight and between leaf fat and carcass extractable fat were higher than between back fat and the same parameters. Therefore, leaf fat may be a more satisfactory index of true body fat than is back fat, although the best index still is the carcass extractable fat, for which the correlation with the empty body fat was 0.99. The offal proximate chemical components were highly correlated with those of the carcass and the empty body. A knowledge of the chemical composition of the offal alone is, therefore, a good reflection of the chemical composition of the empty body. Percent of extractable fat in the empty body, carcass, or offal were positively correlated with fat measures and negatively correlated with all lean measures and with the protein and water. Percents of water and protein were positively correlated with the lean parameters and negatively correlated with all fat characteristics. The saturated fatty acids were positively related to all fat measures and to average daily gain and gross energy of the body and negatively correlated with all lean measures and water and protein. The reverse was true for the unsaturated fatty acids. Also, some strong inverse relationships were found between some unsaturated and saturated fatty acids. The chilled dressing percent was poorly correlated with nearly all physical and chemical measures and, therefore, should not be regarded as a satisfactory index of physical or chemical parameters.

RELATIONSHIPS AMONG SOME PHYSICAL AND CHEMICAL PARAMETERS OF FULL- VERSUS LIMITED-FED YORKSHIRE PIGS SLAUGHTERED AT DIFFERENT LIVE WEIGHTS

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It is well established that feed restriction, when imposed at the right stage of growth of the pig, tends to increase the proportion of lean cuts in relation to fat. Most reports have dealt primarily with physical factors such as growth rate, feed efficiency, back-fat thickness, loin-eye area, percent lean cuts and carcass length. Only a few reports (McMeekan and Hammond, 1939; McMeekan, 1940; Zobrisky *et al.*, 1958) have included a more detailed analysis. Similarly, only a few reports (Lu *et al.*, 1958; Zobrisky *et al.*, 1954, 1958; Gnaedinger *et al.*, 1963; Doornenbal, 1961) have described relationships between physical and chemical measurements of the pig.

The purposes of this investigation were to study (1) influences of slaughter weight and feed restriction on physical characteristics of the pig carcass and (2) relationships between physical carcass measures and chemical components of the body.

Experimental

Thirty closely-related Yorkshire pigs (12 barrows and 18 gilts) were divided into pairs on the bases of sex and ancestry at approximately 45 kg. live weight. One member of each pair was randomly assigned to receive 1.82 kg. of feed daily throughout the experimental period to slaughter at 79, 90 or 102 kg., while the other was continued on *ad libitum* intake throughout. Conventional slaughter procedures were followed. Feed, but not water, was withdrawn approximately 16 hr. prior to slaughter. One-half of each carefully split, dressed carcass was used for conventional physical carcass measurements, while the other half was ground for determination of protein, fat, ash, moisture and gross energy. All other parts (including gastrointestinal tract minus contents, head, respiratory tract and all other internal organs) were pooled, ground and sampled for chemical analysis. These parts are hereafter referred to as "offal". The term "empty body" refers to the whole body minus hair and contents of the intestinal tract. The data were analyzed according to the method of unweighted squares of means for a $2\times2\times3$ arrangement of factors. Correlations were determined on the pooled data disregarding treatment, sex and weight groups.

Results and Discussion

Influence of Slaughter Weight on Carcass and Performance Characteristics. Slaughter weight had manifold effects on carcass measurements of the pig (table 1). The lightest pigs had higher proportions of lean cuts than the two heavy groups. A broad generalization in this respect is that lean cuts diminished in proportion as slaughter weight increased, while the fat cuts increased. More specifically, the 79-kg. group had significantly ($P<.01$) higher four lean cuts as a percent of chilled carcass weight, ham as a percent of chilled carcass weight, shoulder as a percent of chilled carcass weight and lower back-fat thickness, body length, absolute weight of ham, leaf fat and leaf fat as a percent of empty body, than either of the other two groups. However, when the two heaviest groups were compared, the magnitudes of most of these differences were reduced in many cases. Back-fat thickness and percent lean cuts, ham, shoulder and leaf fat, each as a percent of chilled carcass weight, were not significantly different for the 90- and 102-kg. groups. Highly significant differences were observed in body length, gross body calories and net calories gained between the two groups; the 102-kg. group was favored

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TABLE 1. EFFECTS OF PLANE OF NUTRITION AND SLAUGHTER WEIGHT ON CARCASS QUALITY AND PERFORMANCE CHARACTERISTICS OF YORKSHIRE PIGS

	Means					*F* value [a]				
	Weight group			Level of feeding						
Items	79 kg.	90 kg.	102 kg.	Full	Limited	Full *vs.* limited	79 kg. *vs.* 90 kg.	79 kg. *vs.* 102 kg.	90 kg. *vs.* 102 kg.	Error mean squares
Warm dressing percent	75.1	75.3	75.6	75.3	75.4	...	...	...	...	1.7583
Chilled dressing percent	73.0	73.4	73.5	73.1	73.5	...	...	...	...	1.6750
Lean cuts, %	57.8	54.8	54.7	54.8	56.7	13.24	20.70	22.68	...	2.0683
Back fat, cm.	3.3	3.8	4.0	3.9	3.4	17.85	13.19	22.35	1.04	0.1048
Loin eye, $cm.^2$	27.5	28.0	29.6	27.4	29.3	5.08	...	4.68	2.64	4.7451
Body length, cm.	73.7	76.7	80.0	76.5	77.1	1.56	30.64	140 05	38.26	1.4278
Daily gain, kg.	0.64	0.59	0.64	0.77	0.50	183.08	4.93	...	4.89	0.0142
Feed/gain	3.5	3.8	3.6	3.5	3.8	5.66	4.07	1.34	...	0.1145
Days on feed	61.9	81.4	103.7	64.0	100.6	76.30	14.47	68.95	19.54	126.68
Cal. consumed/cal. gained	4.7	4.2	4.5	4.1	4.8	8.44	2.88	...	1.79	0.3587
Gross body energy, therms	254.0	335.3	373.7	328.6	313.4	4.56	87.76	197.92	20.30	362×10^6
Net energy gained, therms	155.4	236.8	275.1	230.0	214.9	4.56	87.76	197.92	20.30	362×10^6
G.E./$wt.^{0.7}$/day/cal. gained, cal. [b]	5.94	3.44	2.46	4.30	2.87	...	...	...	...	...
Carcass/empty body wt., %	81.9	82.4	82.4	82.1	82.3	...	1.52	1.88	...	0.6778
Offal/empty body wt., %	18.1	17.6	17.6	17.8	17.7	...	1.52	1.88	...	0.6777
Ham wt., kg.	12.7	13.9	15.7	13.8	14.4	5.58	12.07	81.32	29.94	0.5385
Ham/lean cuts, %	38.4	37.4	38.2	38.1	38.2	...	...	...	...	1.8248
Ham/chilled carcass wt., %	22.2	20.8	20.8	20.9	21.7	5.52	9.80	9.47	...	0.9517
Ham/empty body wt., %	17.7	16.7	16.7	16.7	17.4	5.04	5.88	6.30	...	0.7764
Wt. of head, kg.	4.7	5.2	5.9	5.1	5.4	10.15	15.26	93.91	32.55	0.0720
Wt. of leaf fat, kg.	0.9	1.3	1.7	1.3	1.3	...	12.71	44.31	9.19	0.0715
Empty body wt., kg.	72.0	83.2	94.1	83.0	83.2	...	217.39	876.63	211.91	2.7761
Loin/lean cuts, %	32.4	33.7	33.4	33.4	32.9	1.09	4.88	3.26	...	1.5338
Loin/chilled carcass wt., %	18.7	18.4	18.2	18.3	18.7	1.87	...	1.85	...	0.6726
Loin/empty body wt., %	14.9	14.8	14.6	14.6	15.0	2.42	...	1.21	...	0.4562
Shoulder/lean cuts, %	29.2	28.4	28.4	28.5	28.8	...	1.80	4.63	...	1.7653
Shoulder/chilled carcass wt., %	16.9	15.6	15.5	15.6	16.4	6.40	11.91	14.31	...	0.6610
Shoulder/empty body wt., %	13.4	12.5	12.4	12.5	13.1	6.29	8.27	10.95	...	0.4954
Head/empty body wt., %	6.5	6.2	6.3	6.2	6.5	8.11	3.52	3.43	...	0.1282
Leaf fat/empty body wt., %	1.3	1.6	1.8	1.6	1.5	...	5.83	14.89	1.95	0.1035
Belly/chilled carcass wt., %	12.4	12.7	12.7	12.7	12.5	1.23	...	1.34	...	0.4320
Belly/empty body wt., %	9.9	10.2	10.2	10.2	10.0	...	1.82	2.04	...	0.2576

[a] *F* values greater than 4.41 (d.f. 1, 18) and less than 8.29 (d.f. 1, 18) indicate significant differences at $P<.05$; those greater than 8.29 at $P<.01$. *F* values less than 1 are not included in the table.
[b] *F* values were not calculated for this parameter.

in all cases. Zobrisky *et al.* (1958) calculated the percent of trimmed ham, loin and shoulder of carcass weight for pigs ranging in weight from 45 to 136 kg. and obtained the same decreasing trend of these lean cuts as the slaughter weight increased.

These results agree fairly well with the findings of Emerson *et al.* (1964), who found that, as the slaughter weight was lowered from 93 to 45 kg., there was a decrease in carcass length, dressing percent and loin-eye area and an increase in the percent of primal and lean cuts.

Both warm and chilled dressing percents tended to increase with slaughter weight, although the differences between slaughter weight groups were not significant at $P<.05$. This same tendency for an increase in dressing percent with weight groups was observed by Zobrisky *et al.* (1958). They obtained significant ($P<.05$) differences between 45.5- *vs.* 68.2-kg. and between 68.2- *vs.* 136.4-kg. slaughter weight groups, but not between 68.2- *vs.* 90.9-kg, nor between 90.9- *vs.* 113.6-kg. groups.

With respect to the efficiency of feed conversion expressed in the conventional unit of feed consumed per kg. gain, the 79-kg. group was most efficient and the 90-kg. group was least efficient. When expressed in calories consumed per calorie gained, the 90-kg. group was most efficient and the 79-kg. group was least efficient. This latter finding is explainable by the fact that the 90-kg. group had the highest empty body fat, while the 79-kg. group had the lowest body fat. Since fat has approximately 2.25 times the caloric value of carbohydrate or protein, it seems logical although not necessarily true that pigs which had the highest content of fat should be more favored in caloric conversion, provided they did not consume 2.25 times the amount of feed consumed by the lean pigs. When caloric efficiency was expressed in terms of gross calories consumed per weight ($kg.^{0.7}$) per day per calorie gained, the values obtained were 5.94, 3.44 and 2.46 cal. for the 79-, 90- and 102-kg. groups, respectively. This further strengthens the argument of higher caloric conversion efficiency of the fatter, heavier pigs than the lighter ones, if the only variable is slaughter weight. Thus, a definite trend for increasing efficiency of caloric utilization could be seen as slaughter weight increased.

Influence of Feed Restriction on Carcass Characteristics and Caloric Efficiency. Two methods were used to express the efficiency of feed conversion: (1) the conventional method of feed per unit of body weight gain, and (2) calories consumed per calorie gained. With either method the full-fed pigs were more efficient than the limited-fed pigs (table 1). These results differ from those reported by Becker (1962) for pigs subjected to the same constant daily intake of 1.82 kg. per head. With respect to caloric conversion it is generally considered that fattening is an expensive and inefficient process. Saint Pierre *et al.* (1934) noted that, when growing-fattening animals were limited-fed, a longer period was required before they reached the desired market weight and the desired degree of fatness. They interpreted this as evidence that, other factors being constant, restricting feed intake would increase the proportion of feed energy required for body maintenance and, therefore, reduce the proportion available for weight gain. The results of the present investigation agree with this concept, although this was not so when caloric conversion efficiency was expressed in terms of calories consumed per weight per day per calories gained. The figures obtained for this calculation were 4.30 and 2.87 calories for full- and limited-fed pigs, respectively. Here it is clear that, when slaughter weight was equal and the only variable was feed restriction, the pigs on restricted feed intake were more efficient calorie converters than the full-fed pigs (table 1).

The full-fed pigs had higher average offal as a percent of empty body weight but lower average carcass and head as percent of empty body weight, but none of these differences was significant. Feed restriction significantly increased amounts of head, shoulder and ham expressed as percent of empty body weight, while it significantly depressed back-fat thickness and net calories gained. The leaf fat and belly expressed as percent of empty body weight were not significantly reduced by feed restriction.

Relationships between Physical and Chemical Measurements. Relationships between the physical fat measurements and the percents of the chemically-determined fat and protein of the empty body, carcass and offal are given in table 2. One relationship often considered is that between certain physical fat measurements, particularly back-fat measurement and the chemically-determined empty body or carcass fat. Back-fat measurement has generally been regarded as the best and most dependable practical index of fatness of pig carcasses (Lu *et al.*, 1958). The comparisons appearing in table 2 show that the leaf fat is more highly correlated with extractable fat of the empty body (0.77), carcass (0.72) or offal (0.87) than back-fat thickness with the same parameters (0.69, 0.72 and 0.39, respectively) and, therefore, offers an index of true fatness of the animal. However, neither the leaf fat nor back-fat thickness was as good an indication of the true empty body fat as the chemically-determined carcass fat (r=0.99). The close relationship between leaf fat and offal fat resulted, because leaf fat is a component of the offal fraction. Of the three physical fat measurements, the belly showed the lowest correlation with the chemically-determined fat.

TABLE 2. CORRELATIONS BETWEEN PHYSICAL FAT MEASUREMENTS AND CHEMICALLY DETERMINED FAT AND PROTEIN IN PIGS

Characteristic	Leaf fat as percent of empty body wt.	Belly as percent of chilled carcass wt.	Belly as percent of empty body wt.	Back-fat thickness
Empty body protein	−.57**	−.36*	−.32	−.67**
Empty body fat	0.77**	0.40*	0.38*	0.69**
Carcass protein	−.56**	−.36*	−.32	−.68*
Carcass fat	0.72**	0.43*	0.40*	0.72*
Offal protein	−.70**	−.21	−.14	−.35
Offal fat	0.87**	0.21	0.20	0.39*

* $P<.05$.
** $P<.01$.

More detailed relationships between the physical and chemical measurements are given in table 3. The highly significant negative relationships between fat and water content are especially evident. Although not new, this relationship strengthens the evidence that the process of fattening as the animal ages is essentially one of replacement of water by fat (Lawes and Gilbert, 1861; Moulton, 1923; McMeekan, 1940; Spray and Widdowson, 1951). The strong inverse relationships observed between the chemically-determined fat and protein showed that, while the protein was not actually being replaced by fat during fattening, it showed a relative decrease as the fat increased (Lawes and Gilbert, 1861; Moulton, 1923; Murray, 1922). Water and protein were highly correlated, as was observed by others (Gnaedinger *et al.*, 1963; Doornenbal, 1961).

The relationship between carcass length and other measures of carcass value has received considerable attention. Whereas some investigators (Engleman *et al.*, 1950; Cummings and Winters, 1951) reported a highly significant positive correlation between car-

TABLE 3. CORRELATIONS[a, b] BETWEEN SELECTED PHYSICAL AND CHEMICAL MEASURES

Item variables	Empty body protein	Empty body fat	Empty body water	Carcass protein	Carcass fat	Carcass water	Offal protein	Offal fat	Gain/ day
Empty body protein, %	...	—.90	0.83	0.99	—.91	0.87	0.81	—.66	—.50
Empty body fat, %	—.90	...	—.97	—.99	0.99	—.98	—.77	0.84	0.21
Empty body water, %	0.83	—.97	...	0.81	—.96	0.98	0.71	—.85	—.09
Carcass protein, %	0.99	—.89	0.81	...	—.91	0.85	0.75	—.64	—.51
Carcass fat, %	—.91	0.99	—.96	—.91	...	—.98	—.75	0.78	0.25
Carcass water, %	0.87	—.98	0.98	0.85	—.98	...	0.75	—.80	—.15
Offal protein, %	0.81	—.77	0.71	0.75	—.75	0.75	...	—.73	—.29
Offal fat, %	—.66	0.84	—.85	—.64	0.78	—.80	—.73	...	—.01
Av. back-fat thickness, cm.	—.67	0.69	—.66	—.68	0.72	—.68	—.35	0.39	0.41
Loin-eye area, cm.^{2}	0.46	—.36	0.33	0.44	—.42	0.41	0.37	—.08	—.31
Gross body energy, therms	—.65	0.85	—.88	—.64	0.82	—.85	—.57	0.86	0.06
Stearic acid, %	0.43	0.26	—.17	—.47	0.33	—.26	—.19	—.08	0.49
Palmitic acid, %	—.51	0.30	—.24	—.44	0.31	—.27	0.43	0.19	0.39
Linoleic acid, %	0.69	—.53	0.46	0.67	—.54	0.52	0.70	—.38	—.57
Palmitoleic acid, %	0.12	—.03	—.04	0.15	—.08	0.03	—.01	0.24	...
Oleic acid, %	0.13	0.01	—.01	0.12	—.03	0.01	—.07	0.15	—.09
Av. body length, cm.	—.18	0.47	—.55	—.19	0.43	—.50	—.29	0.58	—.08
Ham/chilled carcass wt., %	0.68	—.74	0.71	0.71	—.75	0.76	0.48	—.55	—.31
Loin/chilled carcass wt., %	0.46	—.48	0.45	0.46	—.47	0.44	0.37	—.37	—.13
Shoulder/chilled carcass wt., %	0.63	—.68	0.68	0.64	—.69	0.72	0.51	—.51	—.23
Belly/chilled carcass wt., %	—.36	0.40	—.39	—.36	0.43	—.41	—.21	0.21	0.22
Cold dressing percent	0.20	0.09	0.09	0.16	—.11	0.17	0.29	—.03	—.11
Percent lean cuts	0.76	—.82	0.81	0.78	—.84	0.84	0.59	—.61	—.25

[a] Treatment, sex and weight groups have been disregarded.
[b] Correlation of 0.36, $P < .05$; 0.46, $P < .01$.

cass length and percent lean cuts, others (Aunan and Winters, 1949; Zobrisky *et al.*, 1954) found low correlations and Zobrisky *et al.* (1954) obtained a negative correlation for one breed and a positive correlation for another between these two traits. This investigation showed some anomalous relationships explainable by the fact that the data for sex, treatment and weight groups were pooled for correlation analysis. Since the lightest pigs at slaughter were the shortest and had the thinnest back fat, while the heaviest pigs at slaughter were the longest and had the thickest back fat, length would be expected to be positively correlated with back fat.

The lean cuts as a percent of chilled carcass weight showed highly significant positive relationships with most of the other items of lean meat (table 3). This trait was negatively correlated with the fat parameters. These results are in agreement with the observations of Zobrisky *et al.* (1954) and since confirmed by others (Gnaedinger *et al.*, 1963; Doornenbal, 1961) that the percent of lean cuts is inversely associated with back fat and percent of belly and directly associated with the lean traits.

The relationships between chilled carcass dressing percent and other physical or chemical variables were very low and most were nonsignificant. It has often been argued that fat has a greater effect on, and therefore should have a higher relationship with, chilled dressing percent than with the lean portion of the carcass (Hankins, 1953). Correlations between chilled dressing percent and back-fat thickness, loin-eye area, percent lean cuts, empty body fat and carcass fat were 0.03, 0.45, 0.24, 0.09 and —.11, respectively. Although except for loin-eye area these relationships are comparatively low, it appears that the chilled carcass dressing percent was more closely related to the lean content of the body, and, therefore, this trait should be influenced more by the lean than by the fat parameters.

Generally, the saturated fatty acids of the back fat were positively related to the extractable fat of the empty body, carcass and offal and to the back-fat thickness and other physical fat measures, while they were negatively correlated with the protein and water of the empty body, carcass and offal and to all lean measures of the carcass. The situation was the reverse with the unsaturated fatty acids, i.e., these were positively correlated with all characteristics of lean and negatively correlated with all fat measurements. Linoleic acid was more highly related, positively or negatively, to most of the physical and chemical measurements than were the saturated fatty acids. From the fairly strong inverse relationships existing between most of the saturated and unsaturated fatty acids (table 4), it seems that softening of back fat is a phenomenon accomplished by the gradual replacement of dilution of the already existing saturated fatty acids with the unsaturated ones. Furthermore, it was observed that average daily gain was positively related to saturated fatty acids and negatively to the unsaturated ones. Most of these findings are in agreement with the report of Callow (1935), who claimed that a slowly growing pig usually has a slower rate of fat synthesis and deposition, which in turn is related to a softer back fat.

Finally, an examination of the relationships between chemical constituents of the offal, carcass and the empty body shows that the offal proximate constituents were sufficiently highly correlated with those of the empty body to indicate that a reasonably accurate estimate of the chemical composition of the empty body or of the carcass could be achieved by analyzing the offal.

Summary

An experiment was designed using 30 Yorkshire pigs to study the influence of slaughter weight and feed restriction on carcass cut-out data and to relate these physical measurements to the chemically-determined proximate components. As slaughter weight increased from 79 to 102 kg., the percent of all lean cuts decreased significantly, while that of fat cuts and back-fat thickness increased significantly. Absolute amounts of both fat and lean cuts increased with slaughter weight. Feed restriction significantly increased most of the lean parameters studied and reduced the fat measurements. It increased percent of head and reduced the percent of offal (gastrointestinal tract minus contents, head, respiratory tract and all other internal organs). Correlations between leaf fat and empty body weight and between leaf fat and carcass extractable fat were higher than between back fat and the same parameters. Therefore, leaf fat may be a more satisfactory index of true body fat than is back fat, although the best index still is the carcass extractable fat, for which the correlation with the empty body fat was 0.99.

The offal proximate chemical components were highly correlated with those of the carcass and the empty body. A knowledge of the chemical composition of the offal alone is, therefore, a good reflection of the chemical composition of the empty body. Percent of extractable fat in the empty body, carcass, or offal were positively correlated with fat measures and negatively correlated with all lean measures and with the protein and water. Percents of water and protein were positively correlated with the lean parameters and negatively correlated with all fat characteristics. The saturated fatty acids were positively related to all fat measures and to average daily gain and gross energy of the body and negatively correlated with all lean measures and water and protein. The reverse was true for the unsaturated fatty acids. Also, some strong inverse relationships were found between some unsaturated and saturated fatty acids.

The chilled dressing percent was poorly correlated with nearly all physical and chemical measures and, therefore, should not be regarded as a satisfactory index of physical or chemical parameters.

TABLE 4. CORRELATIONS AMONG THE INDIVIDUAL FATTY ACIDS OF THE BACK FAT

Acids	Palmitoleic	Stearic	Oleic	Linoleic
Palmitic	0.16	0.15	—.49*	—.44*
Palmitoleic	....	—.60**	0.08	0.01
Stearic	....	....	—.50**	—.31
Oleic	....	....	....	—.26

* P<.05.
** P<.01.

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