acid. When all has passed into solution, 3 g of potassium iodide is added followed by 0.5 ml of acetyl chloride. Iodine is immediately formed. After gentle stirring for 2–5 min, the contents are diluted with 50 ml 1 M hydrochloric acid and titrated at once with 0.1 N sodium thiosulfate. In order to correct for simultaneous oxidation of iodide by oxygen in the air, it is preferable to carry out a blank determination, although the corresponding thiosulfate volume was found to be very small (<0.1 ml).

Materials. Dimethyl sulfoxide (Fisher Certified Reagent) was used without further purification. Dibenzyl sulfoxide (Schuchardt) was recrystallized from ethanol. M.p. 135° (Ref. 16: 135–136°). The other compounds listed in Table 1 were all of the same purities as previously reported.[17-19]

Acknowledgement. Thanks are due to Professor A. Fredga for his interest in this work and for all facilities placed at the author's disposal.

1. Fries, K. and Vogt, W. *Ber.* **44** (1911) 756.
2. Tiberg, Å. *Ber.* **49** (1916) 2024.
3. Larsson, E. *Svensk Kem. Tidskr.* **49** (1937) 264.
4. Barnard, D. and Hargrave, K. R. *Anal. Chim. Acta* **5** (1951) 536.
5. Legault, R. R. and Groves, K. *Anal. Chem.* **29** (1957) 1495.
6. Glynn, E. *Analyst* **72** (1947) 248.
7. Wimer, D. C. *Anal. Chem.* **30** (1958) 2060.
8. Horner, L. and Kaiser, P. *Ann.* **626** (1959) 19.
9. Bordwell, F. G. and Pitt, B. M. *J. Am. Chem. Soc.* **77** (1955) 572.
10. Oae, S., Kitao, T., Kawamura, S. and Kitaoka, Y. *Tetrahedron* **19** (1963) 817, 1783.
11. Parham, W. E. and Bhavsar, M. D. *J. Org. Chem.* **28** (1963) 2686.
12. Becker, H.-D., Mikol, G. J. and Russel, G. A. *J. Am. Chem. Soc.* **85** (1963) 3412.
13. Smythe, J. A. *J. Chem. Soc.* **95** (1909) 349.
14. Pummerer, R. *Ber.* **43** (1910) 1401.
15. Albright, J. D. and Goldman, L. *J. Am. Chem. Soc.* **87** (1965) 4214.
16. Leonard, N. J. and Johnson, C. R. *J. Org. Chem.* **27** (1962) 282.
17. Allenmark, S. *Acta Chem. Scand.* **15** (1961) 928.
18. Allenmark, S. *Acta Chem. Scand.* **17** (1963) 2717.
19. Allenmark, S. *Acta Chem. Scand.* **19** (1965) 1670, 2081.

Received March 21, 1966.

Significance of Constituents and Processing on the Amino Acid Pattern of Meat Meal

OLLE DAHL

College of Technology, Uppsala 2, Sweden

KAI ÅKE PERSSON

Scan's Centrallaboratorium, Malmö 1, Sweden

From a global point of view a marked deficiency, quantitatively as well as qualitatively, exists with regard to protein. This refers both to man and animal. One source of protein in animal feeding has been and still is the considerable amounts of by-products from slaughterhouses, constituting about one fifth of the meat production. Most of the inedible products are worked up to meat meal by sterilizing, dehydration and defattening. The value of the meal thus obtained is dependent on two factors: raw material and processing technics.

The quality of meat meal has been investigated repeatedly. Swedish meat meals as well as other foodstuffs were analysed by Ågren [1-3] about 15 years ago. For the determination of the amino acid composition Ågren applied the microbiological technique after preceding autoclaving in 2 M HCl at 120°C for 10 h. Tryptophan, however, was determined after alkaline hydrolysis, and cystine, too, was analysed after a separate hydrolysis.

Since these investigations were made new meat meal processing technics have been developed and generally introduced. In addition, the ratio between the various by-products may have changed with time. Although the samples analysed by Ågren were not drawn at random, they do not represent an average composition of meat meal for a longer period. This is of importance to consider as the raw material shows qualitative seasonal changes.

Formerly the wet rendering technics was generally employed for the processing of meat meal. It is still in use in smaller plants. Briefly, this method makes use of direct steam for sterilizing and for separating the fat. Simultaneously, however, also some 30 % of the protein will be extracted and get lost as "glue liquor", which is drawn. The meat and bone residue is then dried in steam jacketed drums at atmospheric pressure. The temperature

is rather high and the drying period long. These conditions may cause damage of some amino acids. According to the dry rendering method now generally applied sterilizing and drying is performed consecutively in a steam jacketed rotating drum. Thus there is no loss of protein and, besides, drying takes place under reduced pressure; hence temperature and drying time are moderate as compared with wet rendering. Finally, the fat is separated by centrifuging or solvent extraction.

Material and analytical methods. Due to this general change of processing it was considered desirable to analyse the present dry rendered quality of meat meal. For this purpose samples were drawn continuously from each lot during a whole year and kept in closed cans under refrigeration. Each lot of meat meal was mixed in a vertical, conical screw mixer. Separate analyses showed that the lots were homogeneous. Two semi-annual samples were prepared by mixing the samples from individual lots in proportion to the size of the lots.

For analysis of the amino acid composition 0.5 g defatted meat meal was hydrolyzed by boiling 16 h in 50 ml 6 M HCl using reflux. The hydrolysate was diluted to 500 ml and pH was adjusted to 2.0. Two ml of this solution was run in a continuously operating amino acid analyzer. The acidic and neutral amino acids were first eluated with a 0.20 M citrate buffer of pH 3.25, then (after proline) the buffer solution was shifted to pH 4.25. The basic amino acids were determined in a separate column, using a 0.35 M citrate buffer of pH 5.28 for elution. Since tryptophan is destroyed by acid hydrolysis, this amino acid was determined separately in the original material, using the method of Graham *et al.*,[4] slightly modified.

In view of the raw material used for meat meal production, *i.e.* meat (condemned meat and cadavers), bone, blood, rind, and smooth muscles like tripe and udder, a comparison was made between the amino acid composition of selected such material (fresh) and that of the two semi-annual samples of meat meal.

Results and discussion. Table 1 lists the percentage of essential and semi-essential amino acids in the two semi-annual samples of meat meal produced in the Scanian district according to the modern dry rendering technics. In addition, Table 1 shows the amino acid pattern of the following materials: Wet rendered meat meal from the Scanian (Kävlinge) district analysed by Ågren,[1] skeletal muscle according to Dahl,[5] rumen and pig's maw according to the present investigation, blood and pig's rind from the literature.[6] Since no protein is lost by dry rendering as opposed to wet rendering, a higher content of protein was found in this case when calculated on a fat- and moisture-free basis, *viz.* about 70 %, and the same in both samples. The content of protein in the wet rendered meat meal [1] was about 60 %, calculated on the same basis. The fat content was about 8 % and 15 % in dry and wet rendered meal, respectively.

Table 1 permits the following conclusions: (1) Within the limits of analytical error the two semi-annual samples of dry rendered meat meal showed the same amino acid composition. Thus, on an average, similar raw material had been used during the two periods; (2) The protein of the dry rendered meat meal produced nowadays has not so favourable an amino acid pattern as had the wet rendered meal analysed previously. This has particularly reference to the contents of methionine and tryptophan, which are only half of those in the protein of the wet rendered meat meal. Among the other essential amino acids the contents of valine and lysine are about 30 % lower in the protein of the dry rendered meal than in that of the wet rendered. The difference in amino acid composition can be explained by the fact that the dry rendered meat meal contains all the protein from collagenous material like bone and rind, while this protein is partially extracted in the wet rendered process and drawn off as "glue liquor" (*cf.* introduction). This conclusion is evident from the amino acid composition of rind, given in Table 1. Whether the different amino acid patterns of the protein in dry and wet rendered meat meal is also due to some other ratio of blood and/or unstriated muscles like tripe etc. in the raw material mixture, is not possible to decide from the amino acid composition of these ingredients (see Table 1: blood, rumen, maw). (3) When comparing the amino acid composition of the meat meals and that of skeletal muscle as a representative of a high quality protein, considerable deficiencies exist. The meat meals contain inadequate amounts of particularly the following amino acids: methionine, tryptophan (does not refer to wet rendered meat meal), isoleucine, lysine and

Table 1. Content of essential and semi-essential amino acids in meat meals and various raw materials. The contents are expressed as per cent by weight of the sum of amino acids present in the hydrolysate.

Protein in	Essential amino acids								Semi-essential amino acids			
	Val	Leu	Ile	Thr	Lys	Met	Phe	Trp	Arg	Cys	His	Tyr
Meat meal, dry rendered, 1st half year	4.7	7.3	2.3	3.3	5.7	1.1	4.2	0.5	6.8	trace	2.7	2.0
Meat meal, dry rendered, 2nd half year	4.8	7.4	2.4	3.3	5.7	1.1	3.9	0.5	6.8	trace	2.6	2.3
Meat meal, wet rendered[a]	6.8	9.7	3.1	3.4	7.9	2.2	4.5	1.1	6.4	0.5	3.2	4.2
Skeletal muscle[b]	5.2	8.3	4.9	4.8	9.6	3.2	4.2	1.3	6.4	0.3	4.4	3.7
Rumen, cow	3.7	6.2	3.0	3.6	5.4	1.6	3.3	0.8	7.4	trace	1.7	2.8
Maw (stomach), pig	4.5	7.5	3.7	4.3	6.5	2.0	4.0	1.1	7.3	trace	2.2	3.4
Blood[c]	8.4	11.4	1.3	4.1	9.0	1.2	6.8	1.8	4.4	1.4	6.4	2.5
Rind (pig skin)[c]	2.8	3.0	1.5	2.2	3.8	0.7	2.1	0.0	7.5	0.1	0.7	0.8

[a] According to Ågren's [1] data on Meat meal II (Kävlinge) after recalculation on the same basis as is valid for the other values in this table. Since Ågren did not list the content of hydroxyproline, the recalculation is made with the assumption that this content was 5 %; deviations of 1—2 % from this figure do not substantially influence the values of the amino acids listed in the table.

[b] According to Dahl,[5] mean values.

[c] According to Block and Weiss [6] and own analyses on certain amino acids.

threonine. Thus, there is a pronounced imbalance in the amino acid composition of the meat meals. The detrimental nutritional effect of this has been confirmed repeatedly, recently by Summers and Fisher [7] as well as Carrie [8] in experiments with non-ruminants. Since non-ruminant require a high quality protein and ruminants do not, it seems more advisable to allot meat meal to the latter group of animals than to the former. For feeding pigs and poultry meat meal from selected raw material, defattened fish meal and also soya-bean meal supplemented with methionine is recommended.

In addition to what has been said it must be emphasized that the situation is even worse than that, which has been possible to conclude from Table 1. The available amounts of especially lysine and methionine, maybe also of other essential amino acids, is generally lower than the percentages found by chemical analysis. By heat and drying during processing certain groups like, for instance, the ε-amino-group of lysine, may react with other groups present in the material, thereby reducing the digestibility of the amino acid. Upon hydrolysis for analysis, however, the bond thus formed is broken and so the non-available part of the amino acid will be added to the available one. For the determination of available lysine alone the method of Carpenter [9] using fluorodinitrophenyl (FDNP, Sanger's reagent) has been successfully applied.

Acknowledgement. The authors are greatly indebted to Prof. T. Storgårds and Mr. B. Lindquist, Engineer, at Mjölkcentralen's (the Dairy Association) laboratory, Stockholm, for running the amino acid analyses in their automatically operating analyzer.

1. Ågren, G. *Acta Chem. Scand.* **3** (1949) 931.
2. Ågren, G. *Acta Chem. Scand.* **5** (1951) 766.
3. Ågren, G. *Acta Chem. Scand.* **6** (1952) 608.
4. Graham, C. E., Smith, E. O., Hier, S. W. and Klein, D. *J. Biol. Chem.* **168** (1947) 711.
5. Dahl, O. *J. Food Sci.* **27** (1962) 5.
6. Block, R. J. and Weiss, K. W. *Amino Acid Handbook*, Thomas, Springfield 1956.
7. Summers, J. D. and Fisher, H. *J. Sci. Food Agr.* **13** (1962) 496.
8. Carrie, M. S. *The Nutritive Value of Meat Meals;* In Papers presented at the 7th Research Conference of the Meat Industry of New Zealand, p. 25. The Meat Industry Research Institute of New Zealand, Hamilton, 26th—27th May 1965.
9. Carpenter, K. J. *Biochem. J.* **77** (1960) 604.

Received March 21, 1966.