Rendered Products in Cutting Edge Nutrition

K.I. Bruerton, Protea Park Nutrition Services, Sorrento, QLD

For most nutritionists in the Australian feed and intensive livestock industries meat and bone meal has always been there – we have grown up with it. The questions we once asked suppliers, such as does it make 50% protein, are less relevant today than in the past. Today, the feed mill manager may well ask the QA manager if the meat and bone meal will pass his HACCP criteria for microbiological content. The nutritionist will be concerned more with its amino acid content and digestibility. But, with those issues in mind, the nutritionist still has to evaluate meat and bone meal on how it fits into his diet formulae in competition with other available ingredients. Therefore, meat and bone will be included in the diet if its nutritional content and price make it economically competitive with alternative sources of nutrients.

What are the advantages of meat and bone meal?

The most obvious one is that meat and bone meal has a high content of protein and therefore is a concentrated source of amino acids. However, there are other nutrients in animal by-products, about which information is now becoming available, that are creating interest amongst animal nutritionists.

Carnitine

L-Carnitine is an amino acid like compound that is formed in the liver from amino acid precursors such as lysine and arginine. Its structure differs from amino acids in that its amine group is not attached to the same carbon atom (Figure 1). L-Carnitine has a major role in fatty acid metabolism where it is required for the transport of long chain fatty acids into the mitochondria where they are oxidized to produce energy. Long chain fatty acids are converted to esters of coenzyme A (CoA) in the cytoplasm of the cell but these are not able to be transported into the mitochondria. The enzyme carnitine-acyl-transferase exchanges carnitine for CoA producing acyl-carnitine, which is able to be transported into the mitochondria. Here another form of carnitine-acyl-transferase recombines the fatty acid with coenzyme A (CoA) to form acyl-CoA, which then undergoes β-oxidation to produce energy (Figure 2). Because of its central role in fat metabolism carnitine may play a role in determining carcass quality in domestic animals.

Fig 1

Structure of L-carnitine

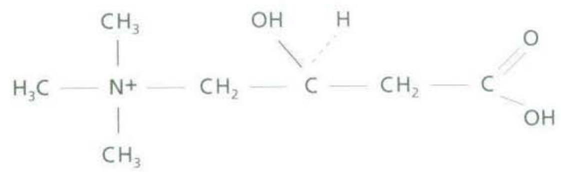
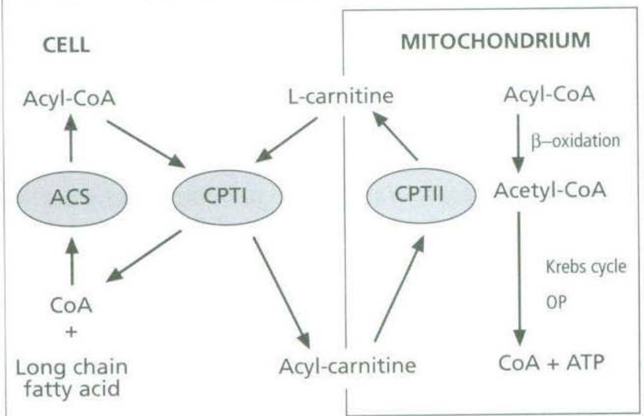


Fig 2

Metabolism of L-carnitine (Lonza Information)



ACS = acyl CoA synthetase; CPTI = carnitine palmitoyl trasnferase type I; CPTII = carnitine palmitoyl trasnferase type II; CoA = Coenzyme A; OP = oxidative phosphorylation

Carnitine is synthesized in adequate amounts by adult animals but in growing animals inadequate synthesis of carnitine may require supplementation through the diet (Borum, 1983). The relevance of L-carnitine to this discussion is that it is contained at much higher concentrations in animal protein meals than is the case for plant products (Table 1). Diets based solely on plant derived ingredients typically contain about 5 ppm of carnitine or less.

Table 1

Approximate levels of carnitine in common feedstuffs. (Lonza Information)

Feedstuff	*mg/kg*	*Feedstuff*	*Mg/kg*
Barley	10	Milk	10
Maize	5	Skim milk	10–30
Wheat	5	Skim Milk Powder	100–300
Triticale	5	Whey Powder	300–500
Wheat Bran	25	Fish meal	60–120
Soybean meal	20	Meat and Bone meal	50–80

Lyvers-Peffer and Odle (2002) showed that in the critical transition phase post-weaning (6–9 weeks of age) pigs fed diets formulated with animal proteins grew significantly faster ($p<0.03$) and ate more feed ($p<0.02$) than those fed diets based on grains and vegetable proteins. Adding synthetic L-carnitine at 100 ppm to either diet had no effect on performance.

It has also been reported that feeding L-carnitine to sows in gestation, lactation, or both increased the number of piglets born alive and increased litter weights at birth and weaning (Musser *et al*, 1999).

In poultry reports of responses to L-carnitine have been reported for broiler breeder hens (Baumgartner, 2003) and for roosters (Neuman et al, 2002). Responses reported by these authors include increased sperm concentration in Roosters (Neuman *et al*, 2002) and increases in hen egg production and reductions in mortality Baumgartner (2003). Again, responses are noted in diets formulated using only vegetable sources of protein. Baumgartner (2003) makes the point that diets formulated from vegetable ingredients contain little carnitine.

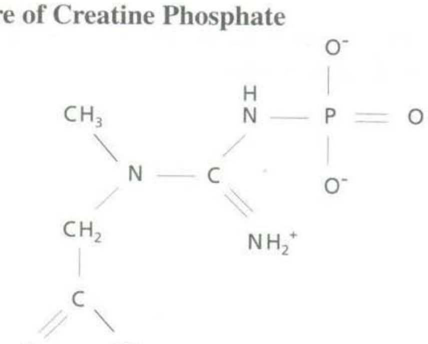
Creatine

Creatine is another metabolite that has come under notice in recent years. Creatine (Figure 3) is a normal constituent of muscle cells. Its role in metabolism is as a high energy storage compound and is involved in the transfer on energy during muscle contraction. Creatine is converted to creatine phosphate by the enzyme creatine kinase, a process which stores energy. This energy is released when the phosphate group is removed and used for muscle contraction.

As is the case with carnitine all animals can manufacture creatine, but there is evidence that supplementation of extra dietary creatine may improve performance. In pigs, Berg and Allee (2001) showed that feeding creatine monohydrate inproved pork quality and Maddock et al (2002) showed that adding creatine to the diet improved growth. However, the effects are variable: Stahl et al (2002) failed to show an effect on meat quality but reported a trend towards a larger eye muscle.

Fig 3

Structure of Creatine Phosphate



Conjugated Linoleic Acid (CLA)

Conjugated linoleic acid is a mixture of isomers of the unsaturated fatty acid linoleic acid (C18:2, n-6). Many geometrical and positional isomers of CLA are known (Dunshea and Ostrowska, 1999). One of the functions of CLA is to be incorporated into the phospholipids of cell membranes. It is now known that a number of isomers of CLA fulfill this role. CLA is found at higher concentrations in animal sources than plant sources, with ruminant products, such as milk and meat containing significant amounts.

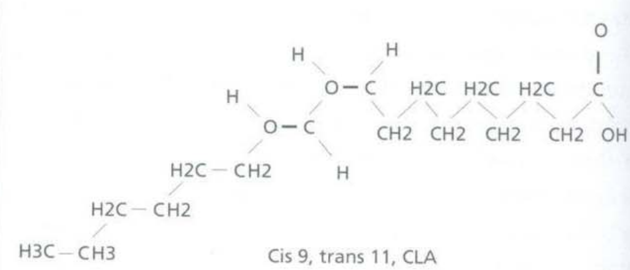
CLA has been shown to have a number of effects in animals, ranging from anti-cancer activity, through modification of the immune response to altering body composition. A comprehensive bibliography of journal articles is listed on the website of Dr Mark Cook of the University of Wisconsin, U.S.A. (www.wisc.edu/cook). Despite this large body of literature, debate continues on just how the accumulated knowledge on CLA will be applied. Cook (2001) sees one of the main functions of CLA as acting to limit the reduction in the performance of animals from the metabolic cost of mounting an immune response. Effects of CLA have been reported on the immune system of poultry (Politis *et al*, 2003) and on carcass quality in pigs (Dunshea and Ostrowska, 1999).

Responses to nutrients such as L-carnitine, creatine and conjugated linoleic acid are mainly seen in animals fed diets based on grain and vegetable protein meals. However, responses are variable and that may be a consequence of the age of transition from starting diets, containing significant inclusions of animal proteins, to growing diets based on vegetable proteins. There seems to be less information available on the responses to these compounds in poultry in poultry. Baker (2001) emphasizes the need to investigate the role of the amines carnitine and creatine in poultry.

Because rendered animal protein meals are a good source of such nutrients, supplementation with pure sources may not be required to maintain normal performance when animal protein meals represent a significant proportion of the diet. This represents a strong nutritional argument for maintaining the presence of animal proteins in the diets of growing pigs and poultry. Only further experimentation will determine whether extra benefits may be gained when diets containing animal by-products are further supplemented.

Fig 4

Structure of one of the major isomers of CLA



Calcium and phosphorus

Adequate supplies of the macro minerals calcium (Ca) and phosphorus (P) are essential for bone development in all animals. Ingredients such as meat and bone meal and fish meal can represent major sources of these nutrients. Van Barneveld *et al* (1994) reported on 8 samples of meat and bone meal sampled in South Australia (Table 2). Although ash level varied from 17.7% to 40.5% the ratio of Ca:P in the ash was effectively constant. These authors showed that %Ca = 0.37 X %ash and %P = 0.18 X %ash and, therefore, that the ratio of Ca:P is 2:1. The correlations of the relationships between ash and Ca and Ash and P are very high at 0.87 and 0.89 respectively. This means that ash levels are a reliable guide to the Ca and P content of meat meals and there is the further advantage that measuring ash is far easier and cheaper than assaying Ca and P individually. The phosphorus in meat and bone meal has been shown to be highly bioavailable to pigs, of the order of 90% (Traylor *et al*, 1998). Estimates for young broilers may be lower at 66%, as reported by Viljoen quoting data from Van der Klis and Versteegh (1996). This compares well with inorganic sources of P (Table 3).

Table 2

Crude protein, ash, calcium, and phosphorus content (g/kg air dry basis) of eight meat and bone meals sold in South Australia in March-April 1994. (After van Barneveld *et al*, 1994)

Sample	*Crude Protein*	*Ash*	*Calcium*	*Phosphorus*	*Dry Matter*
A	479	177	73	38	938
B	444	405	170	77	959
C	522	398	110	55	935
D	480	223	67	35	924
E	520	237	80	40	942
F	510	195	71	36	933
G	460	361	150	70	929
H	365	263	110	51	995

Table 3

Phosphorus availability in selected animal feedstuffs and feed phosphates as measured in 3-wk-old broilers: (Van der Klis and Versteegh, 1996).

Source of P	*Total P (%)*	*Available P (%)*
Bone meal	7.6	59
Fish meal	2.2	74
Meat meal	2.9	65
Meat and bone meal	6.0	66
Calcium sodium phosphate	18.0	59
Dicalcium phosphate (anhydrous)	19.7	55
Dicalcium phosphate (hydrous)	18.1	77
Monocalcium phosphate	22.6	84
Mono-dicalcium phosphate (hydrous)	21.3	79
Monosodium phosphate	22.4	92

Although P is present in significant amounts in most plants, up to 2/3 is not biologically available to monogastric animals, such as pigs and poultry, as it is bound in the form of phytic acid. Monogastrics do not produce phytase enzymes themselves. However, in mature monogastrics there is some microbial digestion of phytate P. The occurrence of phytate in common feed ingredients was extensively reviewed by Ravindran (1996). Enzymes capable of digesting phytate are available for addition to animal feed, and are economic in diets containing only plant derived ingredients. When using such enzymes in diets containing meat and bone meal the economics depend on the efficacy of phytase in improving the digestibility of energy and amino acids in the intestine. Because there is less dependence on phosphorus from plant sources in such diets improvements in the digestibility of phytate P alone are generally insufficient offset the cost of addition of the enzyme.

What are the disadvantages of meat and bone meal?

Of the readily available protein meals only soybean meal matches or surpasses meat and bone meal as a source of amino acids relative to its crude protein level. The main criteria in assessing ingredients as sources of amino acids are the quantity of amino acids, their bioavailability and the consistency in the levels supplied. Amino acid analyses are available from a number of laboratories including the amino acid suppliers Aventis, Degussa, Nippon Soda and Novus. Degussa Corp. has published an extensive summary of many amino analyses of samples taken from many countries. Table 4 shows the amino acid analyses for meat and bone meal and for soybean meal as published by Degussa in their Aminodat v2.0 computer listing. The number of samples, collected on a world-wide basis, of each ingredient is very high, 679 for meat and bone meal and 1916 for soybean meal. Comparing just crude protein levels suggests there is little difference between the two ingredients. If the economically important amino acids lysine and methionine are considered, the former is slightly higher on average in soybean meal and the latter higher in meat and bone. Threonine, generally the third limiting amino acid in pig and broiler diets, is somewhat higher in soybean meal. However, tryptophan, which is likely to be a limiting amino acid in corn based diets, is considerably lower in meat and bone meal than soybean meal. Generally, these differences are readily adjusted by adding crystalline sources of these amino acids, although, clearly the relative value of the ingredients are affected.

Bioavailability of the amino acids is also a major determinant of the economic value of an ingredient. In Table 5 the amino acid digestibilities determined by Degussa for meat and bone meal are compared to those of soybean meal. For pigs the amino acids in meat and bone meal are clearly lower in digestibility that those in soybean meal. In poultry the

Table 4

Amino acid analyses of meat and bone and soybean (Degussa Aminodat 2.0)

	Soybean Meal n = 1916 % AA in Feed Ingredient					Meat and Bone Meal n = 679 % AA in Feed Ingredient			
	Mean	*CV(%)*	*Min*	*Max*		*Mean*	*CV(%)*	*Min*	*Max*
MET	0.64	7.8	0.50	0.78	**MET**	0.67	19.6	0.33	1.28
CYS	0.71	7.1	0.50	0.97	**CYS**	0.49	42.9	0.17	1.84
M+C	1.35	6.5	1.08	1.70	**M+C**	1.16	22.7	0.59	2.62
LYS	2.82	4.8	2.23	3.40	**LYS**	2.43	16.8	1.25	4.06
THR	1.82	4.7	1.55	2.08	**THR**	1.58	17.6	0.96	2.58
TRP	0.62	6.7	0.50	0.83	**TRP**	0.32	25.4	0.14	0.53
ARG	3.42	5.3	2.64	4.07	**ARG**	3.36	9.5	2.48	4.55
ILE	2.10	4.8	1.75	2.42	**ILE**	1.36	20.5	0.81	2.45
LEU	3.54	3.9	2.46	4.09	**LEU**	2.92	18.2	1.78	4.57
VAL	2.23	5.2	1.88	2.75	**VAL**	2.14	18.4	1.28	3.61
HIS	1.22	6.1	0.88	1.51	**HIS**	1.02	26.2	0.45	1.90
PHE	2.35	4.9	1.91	2.74	**PHE**	1.64	18.6	1.01	2.57
TYR	1.68	7.6	1.31	1.88	**TYR**	1.20	10.3	1.02	1.45
GLY	1.99	4.3	1.72	2.37	**GLY**	6.63	10.9	3.85	9.28
SER	2.36	5.1	1.93	3.04	**SER**	1.99	21.8	1.25	4.53
PRO	2.33	8.6	1.63	3.24	**PRO**	4.13	11.2	2.79	6.65
ALA	2.01	4.3	1.67	2.41	**ALA**	3.63	8.7	2.42	4.88
ASP	5.37	4.5	4.46	6.16	**ASP**	3.69	13.9	2.41	5.44
GLU	8.35	5.6	6.96	9.67	**GLU**	5.85	12.9	3.96	8.61
CP	**47.03**	**3.8**	**41.0**	**51.3**	**CP**	**49.9**	**10.1**	**37.1**	**66.6**

Table 5

Amino acid digestibility of soybean meal and meat and bone meal. (Degussa Aminodat 2.0)

	Soybean meal % Digestible		Meat & Bone Meal % Digestible	
Amino Acid	*Swine*	*Poultry*	*Swine*	*Poultry*
Methionine	90	92	77	85
Cystine	86	87	67	74
Lysine	89	90	77	81
Threonine	86	89	74	79
Tryptophan	87	86	73	78
Arginine	93	92	85	84
Isoleucine	88	92	78	84
Leucine	87	92	78	85
Valine	87	90	76	83
Histidine	90	90	76	80

From Degussa Aminodat 2.0. Degussa Corp 2002.

difference is smaller but still in favour of soybean meal. Nutritionists generally formulate broiler and growing pig diets on the basis on digestible amino acid levels so these are what determine the relative economic values of the ingredients.

One of the major disadvantages for meat and bone meal is that it can be variable in nutrient content. This is mainly a case of variation between different sources due to kill mix and processing differences, but in my personal experience variation of product from an individual supplier is not unheard of. If one considers the coefficient of variation (CV) of the level measured of each amino acid (Table 4) it is clear that the average CV for meat and bone meal is nearly 3 times that for soybean meal. Hence the variation in amino acid level is far greater in meat and bone meal than in soybean meal. This can be a problem for formulators if meat and bone meal is coming from several sources. Similarly, the ash levels reported by Van Barneveld *et al* (1994) show similar variation. Variation in Ca and P levels is a major problem for companies, such as broiler integrators, receiving meat and bone meal from a number of sources. It is difficult for the nutritionists to accurately specify meat and bone meal Ca and P when the ash from different suppliers can vary from 22% to 40%. The best one can do under these circumstances is to try and regulate the supply, construct a composite ingredient specification that reflects the delivery schedule and hope the purchasing department can get the suppliers to deliver consistently in the required pattern. In practice that is impossible on a longer term basis so safety factors are built into the specs and these result in economic loss for the user. Needless to say that a comprehensive analytical service is

Table 6

Biogenic amine analyses of meat and bone meal samples.

Sample	Country of origin	Putrescine mg/kg	Cadaverine mg/kg	Histamine mg/kg	Total mg/kg
A	NZ	13	32	5	50
B	AUS	7	8	15	30
C	AUS	42	24	14	80
D	AUS	24	48	8	80
E	AUS	37	79	18	134
F	AUS	45	48	15	108
G	AUS	23	25	12	60
H	AUS	30	37	14	81
I	AUS	15	14	9	38
J	AUS	5	5	13	23
K	AUS	7	5	17	29
L	NZ	110	180	14	304
M	NZ	84	71	6	161
N	AUS	22	39	13	74

required to keep track of the nutrient levels of each supplier's product and that the nutritionists must regularly update the specification of their composite ingredient.

Biogenic amines are another group of compounds that have caused broiler nutritionists concern in recent years. They include such compounds as putrescine, cadaverine and histamine and occur in meat and bone meals, poultry offal meals and fish meals. Although putrescine and histamine are normal constituents of cells, cadaverine is a product of bacterial decomposition. Exogenous histamine has been shown to result in gizzard erosion in poultry (Harry *et al*, 1975). Other authors, adding synthetic mixtures of biogenic amines to broiler and layer feed report no detrimental effects on performance (Miles et al 2000a, Miles et al, 2000b). However, anecdotal evidence from broiler producers suggests that reducing the level of biogenic amines in broiler feed resulted in consistent improvements in feed conversion (Hardie, 2002). Poultry companies regularly measure rendered by-products for the presence of biogenic amines and set standards as to maximum acceptable limits. There are no industry standards for maximum levels of biogenic amines and nutritionists tend to work to their own standards. Samples of biogenic amine analysis of meat and bone meal samples are shown in Table 6. The levels tend to be fairly consistent from individual suppliers. Those suppliers that have consistent kill patterns and render offal within 4-6 hr of killing will have low biogenic amine levels. Those that pick up meat scraps from butchers, or have to wait for a full batch of offal to render, may have higher levels. Potential clients would be well advised to check the quality of the meals from potential suppliers before buying. Of the samples shown in Table 6 only sample 'L' would be cause for concern, although Sample 'M' is marginal. However, histamine levels are low in all samples so toxicity to broilers may not be a concern with any of them. The message for producers of meat and bone meal is to know your own products, to get them analysed for biogenic amines by a reputable laboratory and supply the results to the clients. A high quality set of biogenic amine results is a selling point.

Conclusion

Meat and bone meal has been used extensively in animal nutrition for many years, providing a valuable source of amino acids and minerals. Since coming under threat from problems such the advent of BSE in the UK in the 80's many regulatory authorities and users have questioned its role in pig and poultry diets. Since its disappearance from European diets a number of compounds contained in meat by-products, such as those mentioned in this paper, have been shown to be important in animal nutrition. These discoveries add weight to the continued nutritional relevance of rendered by-products and are valuable marketing points for producers. Further emphasis on production quality and consistency by producers will increase confidence amongst customers and convince them that rendered by-products have a valuable place in diets for pigs and poultry.

References:

Baker, D.H. (2001). Challenges and priorities in poultry nutrition research. Multi-State Nutrition and Feeding Conference, Purdue University. (www.ag.ansc.purdue.edu/poultry/multistate/multistate.htm).

Baumgartner, M. (2003). Breeders perform better with L-carnitine. International Hatchery Practice 17(4): 13-15.

Berg, E.P., and Allee, G.L. (2001). Creatine monohydrate supplemented in swine finishing diets and fresh pork quality: I. A controlled laboratory experiment. J. Anim. Sci. 79: 3075-3080.

Borum, P.R. (1983) Carnitine. Ann. Rev. Nutr. 3:233-259.

Cook, M.E. (2001) Interface between management and the chicken. Poultry Beyond 2005. Poultry Industry Assoc. of N.Z. 94-104.

Hardie, M (2002). Personal communication.

Harry, E.G., Tucker, J.F., and Laursen-Jones, A.P. (1975). The role of histamine and fish meal in the incidence of gizzard erosion and proventricular abnormalities in the fowl. Br. Poultry Sci. 16: 69-78.

Irish G. (2003). Degussa, Australia. Personal communication.

Lyvers-Peffer, P. and Odle, J. (2002). Effects of dietary L-carnitine supplementation on weanling pig performance. N.C. State University, Annual Swine Report.

Maddock, R.J., Bidner, B.S., Carr, S.N., McKeith, F.K., Berg, E.P., and Savell, J.W. (2002) Creatine monohydrate supplementation and the quality of fresh pork in normal and halothane carrier pigs. J. Anim. Sci. 80:997-1004.

Miles, R.D., Wilson, H.R., Bressman, R.B., Butcher, G.D., and Comer, C.W. (2000a). Biogenic amines 1: Influence of feeding various dietary concentrations of eight biogenic amines individually or in combination to broilers. Poultry Sci. 79(Suppl. 1) S192.

Miles, R.D., Wilson, H.R., Bressman, R.B., Butcher, G.D., and Comer, C.W. (2000b). Biogenic amines 2: Influence of feeding various biogenic amines individually or in combination to broilers and layine hens. Poultry Sci. 79(Suppl. 1) S193.

Musser, R.E., Goodband, R.D., Tokach, M.D., Owen, K.Q., Nelssen, J.L., Blum, S.A., Dritz, S.S., and Civis, C.A. (1999). Effects of L-carnitine fed during gestation and lactation on sow and litter performance. J. Anim. Sci. 77:3289-3295.

Neuman, S.L., Lin, T.L. and Hester, P.Y. (2002). The effect of dietary carnitine on semen traits of White Leghorn roosters. Poultry Sci. 81: 495-503.

Politis, I., Dimopolou, M., Voudouri, A., Noikokyris, P., and Feggeros, K. (2003) Effects of dietary conjugated linoleic acid isomers on several functional properties of macrophages and heterophils in laying hens. Br. Poultry Sci. 44(2):203-210.

Ravindran, V. (1996). Occurrence of phytic acid in plant feed ingredients. In: Phytase in Animal Nutrition and Waste Management. A BASF reference manual. Eds Coelho, M.B. and Kornegay, E.T. 85-92.

Traylor, S.L., Cromwell, G.L., and Lindemann, M.D. (1998). Bioavailability of phosphorus in meat and bone meal for growing pigs. J. Anim. Sci. 76(Suppl. 2):55.

Van Barneveld, R., Park, S and Cameron, L. (1994). A survey of meat and bone meal quality. Pig Industry News, September 1994 13-15. (Rural Press Ltd, 123 Greenhill Rd. Unley, S.A. 5061)

Van der Klis, J.D. and Versteegh, H.A.J. (1996). De opneembaarheid van van forfor en de afbraak van inositolfosfaten bij verschillende plantaadige grondstoffen. Het effect ven het gehalte opneembaar fosfor en calcium bij vleeskuikens. Rapport ID-DLO 96.033.

Viljoen J. Quality of feed phosphates supplements for animal nutrition. South African Society of Animal Science (http//:www.sasas.co.za/popular/popular.html)