Amino acid and protein supplementation of defatted cottonseed flour[1]

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SUMMARY

Defatted cottonseed flour (50% protein) was supplemented with synthetic amino acids and other protein concentrates to learn about its deficiencies, and how to improve its nutritive quality. It was found that lysine is the first limiting amino acid, followed by threonine and methionine, as judged by results obtained with rats. Addition of isoleucine did not improve the protein quality of cottonseed flour. Of the protein supplements used, with the exception of meat flour those from animal origin gave a better improvement than those of vegetable origin. Fish protein concentrate proved to be the best, followed by casein and skimmilk. As far as the vegetable protein concentrate is concerned, soybean seemed to be equal to torula yeast. The significance of the response obtained, either by the addition of synthetic amino acids or protein concentrates to cottonseed flour, is discussed in terms of the improvement achieved in its protein quality and quantity. The practical implications of these results are also pointed out, mainly those concerning the formulation of protein-rich foods.

INTRODUCTION

During the last few years attention has been given to cottonseed flour, as a source of protein to meet the needs of malnourished populations (1). Various protein-rich food mixtures have been formulated using cottonseed flour (1-3), some of which are already being consumed by small population groups.

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Even though cottonseed protein is now available for human consumption, it is considered that if its essential amino acid pattern were to be improved by the addition of the appropiate amino acid or protein supplements, a better product could be obtained. Cottonseed protein is lysine-deficient (4, 5) and this deficiency becomes more acute during the processing for oil extraction (5, 6). Several investigators (7, 8) have reported that lysine addition increases the protein quality of cottonseed. Further improvements have been accomplished through the simultaneous addition of lysine and methionine (9), and of lysine and isoleucine (10-12). These findings need to be corroborated, since animals fed vegetable protein mixtures formulated with cottonseed flour and supplemented with isoleucine, do not show any favorable response (13). Although the three amino acids can be added, it is likely that the addition of methionine and isoleucine will not improve the quality of cottonseed protein sufficiently to compensate their high cost, especially that of isoleucine. Therefore, it would seem preferable to add all amino acids as proteins, particularly those rich in lysine, methionine and isoleucine.

The results of several experiments designed to study the amino acid deficiencies of deffated cottonseed flour are presented. The possibility and means of improving its protein quality by protein supplementation are also discussed.

MATERIAL AND METHODS

Experimental Animals

All of the trials were carried out in weanling white rats of the Wistar strain from the INCAP colony. Eight rats per group were distributed at random, according to their weight, so that the average initial weight per group did not differ by more than 1 gram. Each group consisted of 4 male and 4 female rats; they were placed in individual all-wire cages with raised screen bottoms. Feed and water were supplied *ad libitum* for a period of 28 days. Changes in weight and amount of food consumed were determined every 7 days.

Diets

Amino acid supplementation. Animals were fed a basal diet with the following composition: pre-press solvent extracted

cottonseed flour, 20%; mineral mixture, 4% (14); refined cottonseed oil, 5%; cod liver oil, 1%, and corn starch was used to adjust to 100 grams. All diets were supplemented with 5 ml of a complete vitamin solution per 100 g (15). Amino acids were added to the basal diet in the amounts described under Results, and their weight replaced an equal weight of cornstarch.

Protein supplementation. The same basal diet was used in these experiments; however, 2, 4, 6, 8, 10 and 12% of several animal and vegetable protein concentrates were added, replacing an equal weight of cornstarch. Casein, skimmilk, meat flour, fish protein concentrate, soybean flour and torula yeast were used as protein supplements, on the basis of their protein and lysine content. Table 1 presents the protein, lysine, methionine and threonine content of the supplements tested. Since the protein content of the basal diet increased with the different levels of supplementation used, this was also supplemented with increasing amounts of cottonseed flour which provided the same amounts of protein as the supplements. This procedure allowed comparison of results at equal levels of protein in the diet.

RESULTS

Amino Acid Supplementation

As shown in Table 2 significant improvement was obtained in both weight gain and protein efficiency ratio (PER) (average weight gain/average protein intake), by adding 0.1 - 0.2% lisine HCl. However, the response was below that obtained from the casein control group. Addition of only methionine or of methionine plus lysine did not result in a better performance than that achieved with lysine supplementation alone.

The addition of isoleucine together with lysine and methionine did not improve growth nor PER. Increase in weight gain and PER by lysine addition is shown in Table 3, but a further improvement was not observed when lysine and methionine were added together. On the other hand, supplementation with lysine and threonine increased both growth and PER values significantly above those obtained from lysine supplementation alone. A further slight improvement resulted

when cottonseed protein was supplemented with methionine in the presence of lysine and threonine. Isoleucine did not produce changes in weight gain and PER when added with lysine and methionine or with lysine, methionine and threonine.

Protein Supplementation

In all of the following results, comparisons were made between levels of the same supplement, as well as between the responses obtained at equivalent levels of protein derived from the supplement itself and from cottonseed flour.

Casein. The results of this study are presented in Table 4. The addition of 2 - 6% casein caused a significant increase in average weight gain, PER and feed efficiency (FE). No further increase in PER values was obtained when greater amounts of casein were used, although small increases in weight gain and FE were observed; these were comparable to those obtained when higher amounts of cottonseed protein were added to the basal diet. It should be pointed out that in all cases, weight gain, PER and FE were superior for the animals fed the diets supplemented with the various casein levels than those exhibited by the control group consuming cottonseed flour. This was true except for the 8 and 10% casein supplemental levels, which induced a weight gain similar to that obtained with the groups fed the 18 and 20% cottonseed flour diets.

Skimmilk. Table 5 shows the results of this experiment. Addition of 2% skimmilk increased weight gain and PER, while higher levels of skimmilk slightly increased growth rate but did not induce any change in PER.

The response of animals was similar with higher levels of cottonseed flour when this was added in amounts above 2.6%; the PER did not change, and the FE improved in both cases. However, these values improved with the supplemented cottonseed flour. Differences in weight gain and PER between the groups fed skimmilk and cottonseed flour were larger for the animals supplemented with 6, 8 and 10% levels of skimmilk than for the groups that received 4.0, 5.3 and 6.6% cottonseed flour.

TABLE No. 1

PROTEIN, LYSINE, METHIONINE, AND THREONINE CONTENT OF VARIOUS FOODS TESTED AS SUPPLEMENTS FOR COTTONSEED FLOUR

Supplement	Protein[1] %	Lysine g/16 gN	Methionine[2] g/16 gN	Threonine g/16 gN
Skimmilk[3]	35.6	7.94	3.41	4.70
Soybean flour[4]	50.0	6.32	3.12	3.94
Fish protein concentrate[5]	82.5	9.71	2.66	5.76
Casein[6]	89.3	8.06	3.49	4.30
Torula yeast[7]	50.0	8.00	2.20	6.00
Meat flour[8]	40.0	5.25	2.21	3.09
Cottonseed flour[9]	50.2	3.45*	2.16	3.89

The amino acid data were taken from: FAO. **Amino Acid Content of Foods and Biological Data on Proteins.** Rome, Italy, FAO, 1968.

1 Protein = % N x 6.25
2 Methionine + cystine.
3 United Nations Children's Fund (UNICEF).
4 General Mills, Minneapolis, Minn., U.S.A.
5 Viobin Corporation, Monticello, Illinois, U.S.A.
6 N. B. Co., Cleveland, Ohio, U.S.A.
7 Lake State Yeast Corporation, Rhinelander, Wisconsin, U.S.A.
8 A commercial product from Nicaragua, Central America.
9 A commercial product, processed by pre-press solvent extraction.
* Available lysine.

TABLE No. 2

AMINO ACID SUPPLEMENTATION OF COTTONSEED PROTEIN CONCENTRATE

Amino acid	Amunt added %	Average weight gain, g	PER[1]
None	-	94* ± 5.7**	2.16 ± 0.07**
L-lysine HCl	0.1	107 ± 7.8	2.46 ± 0.07
L-lysine HCl	0.2	115 ± 5.8	2.52 ± 0.07
L-lysine HCl	0.3	114 ± 6.7	2.38 ± 0.05
Casein	-	118 ± 6.9	2.78 ± 0.09
None	-	91*** ± 4.8**	2.17 ± 0.05**
DL-methionine	0.1	87 ± 4.2	1.97 ± 0.05
DL-methionine	0.2	86 ± 5.4	2.08 ± 0.08
L-lysine HCl DL-methionine	0.2 0.1	105 ± 4.5	2.31 ± 0.06
L-lysine HCl DL-methionine	0.2 0.2	106 ± 3.8	2.34 ± 0.05
L-lysine HCl DL-methionine L-isoleucine	0.2 0.1 0.1	101 ± 6.1	2.41 ± 0.07
L-lysine HCl DL-methionine L-isoleucine	0.2 0.2 0.1	104 ± 3.1	2.43 ± 0.04

1 PER = protein efficiency ratio.
* Average initial weigth = 47 g.
** Standard error of mean.
*** Average initial weight = 44 g.

TABLE No. 3

AMINO ACID SUPPLEMENTATION OF COTTONSEED PROTEIN CONCENTRATE

Amino acid	Amount added %	Average weight[1] gain, g	PER[2]
None		98 ± 3.8*	2.30 ± 0.03*
L-lysine HCl	0.20	106 ± 7.8	2.58 ± 0.07
L-lysine HCl DL-methionine	0.20 0.05	113 ± 6.9	2.49 ± 0.06
L-lysine HCl DL-threonine	0.20 0.10	124 ± 4.8	2.71 ± 0.07
L-lysine HCl DL-isoleucine	0.20 0.10	96 ± 8.9	2.42 ± 0.09
L-lysine HCl DL-methionine DL-threonine	0.20 0.05 0.10	136 ± 9.4	2.90 ± 0.13
L-lysine HCl DL-methionine DL-isoleucine	0.20 0.05 0.10	116 ± 5.3	2.56 ± 0.05
L-lysine HCl DL-methionine DL-threonine DL-isoleucine	0.20 0.05 0.10 0.10	130 ± 8.3	2.81 ± 0.06

1 Average initial weight = 48 g.
2 PER = protein efficiency ratio.
* Standard error of mean.

TABLE No. 4

SUPPLEMENTA TION OF COTTONSEED PROTEIN CONCENTRATE WITH VARIOUS LEVELS OF CASEIN

Casein added %	Average weight[1] gain g	PER[2]	FE[3]	Cottonseed flour[4] added %	Average weight[1] gain g	PER[2]	FE[3]	Difference in weight gain[5] g
0	92 ± 3.2*	2.44 ± 0.05	4.10 ± 0.08*	-	-	-	-	-
2	141 ± 6.5	2.62 ± 0.05	3.24 ± 0.06	3.6	122 ± 5.4*	2.40 ± 0.06	3.54 ± 0.08*	19
4	143 ± 10	2.44 ± 0.10	3.05 ± 0.13	7.1	135 ± 6.4	2.19 ± 0.04	3.36 ± 0.07	8
6	153 ± 13	2.25 ± 0.11	2.94 ± 0.15	10.7	145 ± 7.1	2.07 ± 0.05	3.15 ± 0.09	8
8	142 ± 13	2.02 ± 0.10	2.94 ± 0.15	14.4	144 ± 9.4	1.93 ± 0.07	3.06 ± 0.12	-2
10	155 ± 10	1.93 ± 0.08	2.76 ± 0.11	17.9	156 ± 10	1.81 ± 0.07	2.95 ± 0.12	-1
12	163 ± 12	1.91 ± 0.08	2.54 ± 0.10	21.4	157 ± 10	1.75 ± 0.08	2.75 ± 0.11	6

1 Average initial weight = 47 g.
2 PER = protein efficiency ratio.
3 FE = feed efficiency.
4 Amount of cottonseed protein concentrate providing the same amounts of protein as those derived from the various levels of casein used.
5 Difference between average weight gain of animals fed the experimental and the control diets.
* Standard error of mean.

TABLE No. 5

SUPPLEMENTATION OF COTTONSEED PROTEIN CONCENTRATE WITH VARIOUS LEVELS OF SKIMMILK

Skimmilk added %	Average weight[1] gain g	PER[2]	FE[3]	Cottonseed flour[4] added %	Average weight[1] gain g	PER[2]	FE[3]	Difference in weight gain[5] g
0	80 ± 4.5*	2.15 ± 0.06*	4.67 ± 0.12*	-	-	-	-	-
2	105 ± 2.0	2.33 ± 0.03	4.05 ± 0.07	1.3	92 ± 3.1*	2.18 ± 0.04*	4.29 ± 0.07*	13
4	109 ± 5.2	2.29 ± 0.10	3.83 ± 0.10	2.6	104 ± 4.8	2.17 ± 0.04	4.05 ± 0.07	5
6	125 ± 8.4	2.32 ± 0.05	3.55 ± 0.08	4.0	106 ± 5.6	2.15 ± 0.04	4.07 ± 0.22	19
8	136 ± 9.0	2.33 ± 0.04	3.34 ± 0.06	5.3	114 ± 7.7	2.05 ± 0.06	3.84 ± 0.12	22
10	144 ± 8.8	2.29 ± 0.04	3.22 ± 0.06	6.6	115 ± 4.8	2.03 ± 0.04	3.69 ± 0.07	29
12	141 ± 8.7	2.27 ± 0.08	3.11 ± 0.11	7.9	136 ± 7.9	2.11 ± 0.04	3.39 ± 0.07	9

1 Average initial weight = 46 g.
2 PER = protein efficiency ratio.
3 FE = feed efficiency.
4 Amount of cottonseed protein concentrate providing the same amounts of protein as those derived from the various levels of skimmilk used.
5 Difference between average weight gain of animals fed the experimental and the control diets.
* Standard error of mean.

TABLE No. 6

SUPPLEMENTATION OF COTTONSEED PROTEIN CONCENTRATE WITH VARIOUS LEVELS OF MEAT FLOUR

Meat flour added %	Average weight[1] gain g	PER[2]	FE[3]	Cottonseed flour[4] added %	Average weight[1] gain g	PER[2]	FE[3]	Difference in weight gain[5] g
0	99 ± 7.2*	2.53 ± 0.04*	3.95 ± 0.07*	-	-	-	-	-
2	104 ± 5.6	2.45 ± 0.06	3.79 ± 0.10	1.6	100 ± 6.9*	1.96 ± 0.04*	3.77 ± 0.08*	4
4	99 ± 4.2	2.22 ± 0.04	3.89 ± 0.08	3.2	110 ± 5.3	2.12 ± 0.05	3.66 ± 0.09	-11
6	106 ± 4.0	2.17 ± 0.04	3.72 ± 0.06	4.8	123 ± 8.4	1.92 ± 0.04	3.48 ± 0.07	-17
8	108 ± 6.7	2.06 ± 0.03	3.68 ± 0.06	6.4	129 ± 5.9	1.91 ± 0.03	3.28 ± 0.06	-21
10	123 ± 6.6	2.17 ± 0.10	3.34 ± 0.17	8.0	140 ± 6.8	1.96 ± 0.04	3.28 ± 0.06	-17
12	123 ± 4.3	2.01 ± 0.02	3.36 ± 0.04	9.6	140 ± 9.8	1.80 ± 0.04	3.00 ± 0.07	-17

1 Average initial weight = 47 g.
2 PER = protein efficiency ratio.
3 FE = feed efficiency.
4 Amount of cottonseed protein concentrate providing the same amounts of protein as those derived from the various levels of meat flour used.
5 Difference between average weight gain of animals fed the experimental and the control diets.
* Standard error of mean.

TABLE No. 7

SUPPLEMENTATION OF COTTONSEED PROTEIN CONCENTRATE WITH VARIOUS LEVELS OF FISH PROTEIN CONCENTRATE

Fish protein concentrate added %	Average weight[1] gain g	PER[2]	FE[3]	Cottonseed flour[4] added %	Average weight[1] gain g	PER[2]	FE[3]	Difference in weight gain[5] g
0	100 ± 7.0*	2.36 ± 0.09*	4.26 ± 0.16*	-	-	-	-	-
2	132 ± 11.0	2.55 ± 0.08	3.38 ± 0.11	3.2	120 ± 7.2*	2.24 ± 0.06*	3.86 ± 0.10*	12
4	144 ± 8.1	2.40 ± 0.05	3.14 ± 0.07	6.4	133 ± 9.7	2.24 ± 0.06	3.39 ± 0.10	11
6	163 ± 9.7	2.36 ± 0.08	2.85 ± 0.09	9.6	141 ± 10.0	2.14 ± 0.06	3.17 ± 0.09	22
8	161 ± 17.0	2.09 ± 0.14	2.99 ± 0.23	12.8	154 ± 8.2	2.04 ± 0.05	3.00 ± 0.07	7

1 Average initial weight = 45 g.
2 PER = protein efficiency ratio.
3 FE = feed efficiency.
4 Amount of cottonseed protein concentrate providing the same amounts of protein as those derived from the various levels of fish protein concentrate used.
5 Difference between average weight gain of animals fed the experimental and the control diets.
* Standard error of mean.

TABLE No. 8

SUPPLEMENTATION OF COTTONSEED PROTEIN CONCENTRATE WITH VARIOUS LEVELS OF SOYBEAN FLOUR

Soybean added %	Average weight[1] gain g	PER[2]	FE[3]	Cottonseed flour[4] added %	Average weight[1] gain g	PER[2]	FE[3]	Difference in weight gain[5] g
0	109 ± 5.7*	2.47 ± 0.05*	4.17 ± 0.11*	-	-	-	-	-
2	121 ± 9.0	2.40 ± 0.09	3.81 ± 0.14	2	103 ± 9.9*	2.27 ± 0.09*	4.06 ± 0.17*	18
4	124 ± 5.3	2.33 ± 0.05	3.58 ± 0.09	4	110 ± 4.3	2.17 ± 0.03	3.84 ± 0.56	14
6	142 ± 6.9	2.37 ± 0.05	3.26 ± 0.07	6	134 ± 9.5	2.22 ± 0.06	3.48 ± 0.11	8
8	165 ± 13.0	2.38 ± 0.09	3.03 ± 0.11	8	140 ± 5.2	2.14 ± 0.05	3.34 ± 0.05	25
10	146 ± 11.0	2.10 ± 0.09	3.20 ± 0.13	10	154 ± 9.0	2.08 ± 0.05	3.21 ± 0.07	-8
12	148 ± 10.0	2.10 ± 0.07	3.00 ± 0.10	12	152 ± 8.8	2.04 ± 0.06	3.08 ± 0.09	4

1 Average initial weight = 48 g.
2 PER = protein efficiency ratio.
3 FE = feed efficiency.
4 Amount of cottonseed protein concentrate providing the same amounts of protein as those derived from the various levels of soybean flour used.
5 Difference between average weight gain of animals fed the experimental and the control diets.
* Standard error of mean.

TABLE No. 9

SUPLEMENTATION OF COTTONSEED PROTEIN CONCENTRATE WITH VARIOUS LEVELS OF TORULA YEAST

Torula yeast added %	Average weight[1] gain g	PER[2]	FE[3]	Cottonseed flour[4] added %	Average weight[1] gain g	PER[2]	FE[3]	Difference in weight gain[5] g
0	88 ± 3.5*	2.04 ± 0.08*	4.95 ± 0.20*	-	-	-	-	-
2	112 ± 5.0	2.15 ± 0.04	4.23 ± 0.07	2	103 ± 5.4*	2.12 ± 0.05*	4.30 ± 0.11*	9
4	118 ± 6.8	2.19 ± 0.04	3.80 ± 0.07	4	108 ± 3.8	2.02 ± 0.06	4.14 ± 0.12	10
6	139 ± 7.6	2.23 ± 0.08	3.46 ± 0.11	6	132 ± 4.0	2.09 ± 0.04	3.69 ± 0.08	7
8	142 ± 9.5	2.12 ± 0.08	3.40 ± 0.13	8	129 ± 4.6	1.78 ± 0.14	3.76 ± 0.11	13
10	150 ± 9.1	2.04 ± 0.08	3.29 ± 0.13	10	131 ± 8.2	1.77 ± 0.06	3.80 ± 0.14	19
12	139 ± 11.0	2.00 ± 0.08	3.15 ± 0.13	12	145 ± 8.5	1.88 ± 0.05	3.34 ± 0.10	-6

1 Average initial weight = 48 g.
2 PER = protein efficiency ratio.
3 FE = feed efficiency.
4 Amount of cottonseed protein concentrate providing the same amounts of protein as those derived from the various levels of torula yeast used.
5 Difference between average weight gain of animals fed the experimental and the control diets.
* Standard error of mean.

Meat flour. The results of this trial summarized in Table 6 show very little supplementary value derived from the addtion of meat protein to conttonseed flour. In general better weight gain, PER and FE were observed when cottonseed flour was added to the basal diet.

Fish protein concentrates. The addition of 2% fish protein concentrate increased weight gain, PER and FE significantly, as revealed in Table 7. Higher amounts increased these values only slightly, although they surpassed those observed when the basal diet was supplemented with cottonseed flour.

Soybean flour. The results in Table 8 indicate that the PER did not increase when the basal diet was supplemented with soybean flour, even though a highly significant increase in weight gain and FE was obtained. As in the previous cases, the addition of cottonseed flour to the basal diet improved weight gain, and FE, but not the PER.

Torula yeast. The results of supplementing the cottonseed flour basal diet with different levels of yeast are summarized in Table 9. The highest weight gain was observed when 10% yeast was added to the basal diet, but with no effect on the PER. A progressive improvement in FE was observed as the level of torula yeast added to the basal diet increased.

The PER response to yeast was minimum and in no case better than that achieved when the basal diet was supplemented with cottonseed flour.

DISCUSSION

The results obtained from the amino acid supplementation studies, carried out by several investigators on various experimental animals (4, 7, 8), have revealed that lysine is the first limiting amino acid in cottonseed protein. Findings of the study described herein are in agreement with previously published information. This is true not only because cottonseed protein without previous processing is already lysine-deficient (7, 16), but also because this deficiency becomes more acute with processing due to the fact that this amino acid reacts both with gossypol and carbohydrates (17-19). The results obtained with the various protein supplements

tested in our study also indicate that cottonseed is deficient in lysine, since those proteins containing higher amounts of this amino acid induced a higher improvement in the quality of defatted cottonseed flour.

Several authors have also indicated that methionine is the second limiting amino acid in cottonseed protein (4, 20). The results of the present research indicate, however, that threonine rather than methionine is the second limiting amino acid. This fact was revealed by the consistent increase boserved in PER and weight gain when threonine was added together with lysine. Furthermore, the addition of methionine plus lysine either decreased the PER and weight gain of the animals, or caused no change in these measurements.

Amino acid supplementatioon of INCAP Vegetable Mixture 9 also showed that threonine is an important amino acid and that it should be added if a significant increase in the protein quality of the mixture is to be obtained (13). Of the protein supplements added, casein and skimmilk provided higher amounts of threonine than those with the greatest content of lysine, thus improving the quality of cottonseed flour.

According to our results, methionine is the third limiting amino acid, while isoleucine —added in the presence of lysine, threonine and methionine— did not improve either growth or PER; on the contrary, a slight decrease in these measurements was observed. These results contradict those reported by Fisher (21) for the baby chick. It is possible that because they have a faster growth rate than weanling rats, baby chicks may be more sensitive to methionine and isoleucine supplementation, once lysine is added to cottonseed protein. Observations reported herein show that supplementation with the appropriate amino acids, always resulted in significantly higher PER values than when the diets were supplemented with whole proteins. On the other hand, the average weight gain obtained was higher when protein supplements were used. These differences in response may be explained in terms of the influence that protein level has both on the PER and on growth rate (22, 23). Addition of protein supplements increased the total protein content of the diet, and at the same time, had a concomitant decreasing effect on PER but not on

weight gain. Amino acid supplementation improved the protein quality but not its quantity.

Among the various supplements studied, animal proteins seemed to be superior to those of vegetable origin except for meat flour which gave a poor performance. Results from experiments with swine have also shown the poor supplementary value that meat flour has on cottonseed protein (24). Fish protein concentrate appears to be the best animal supplement, followed by casein and skimmilk. Soybean protein was slightly better than torula yeast, although the differences in both PER and weight gain were relatively small and not consistent for each level of supplementation.

Determination of the amount of supplement that gives the best performance is difficult to estimate in experiments carried out under the conditions described in this paper. The results indicated that as the supplement increased, weight gain also increased and the FE improved; the protein efficiency ratio increased somewhat, and then decreased. These relationships between the parameters cited and the level of supplement used, make it difficult to decide on a specific level. This was, therefore, the reason why higher levels of cottonseed were used as reference for each level of supplement added. However, estimation is difficult even with a control of this type. Therefore, the level of each supplement giving the best performance was chosen not only from the results presented, but also based on the minimum level of supplement providing 0.2% lysine, which is the first limiting amino acid in cottonseed, and the amount stated is the one needed to balance the other essential amino acids. On this basis, it is suggested that improvement in the protein quality of 20 g of cottonseed flour with 50% protein is attained from the individual minimal addition of 7 g of skimmilk powder, 7 g of soybean flour, 3 g of fish protein concentrate, 6 g of casein, 6 g of yeast and 10 or 12 g of meat flour. These levels also provide ample amounts of threonine and methionine, amino acids that —after lysine— are deficient in this order in cottonseed flour, according to the results presented herein.

The results from the protein supplementation studies described in this paper can be used as a basis for the formulation of protein-rich foods. For example, a mixture prepared with cottonseed flour and fish protein concentrate could be calcu-

lated from the results shown in Table 7. If 3% fish protein concentrate is accepted as the optimum amount and a 25% protein-rich food is desired, it could contain 40 g of cottonseed flour and 6 g of fish protein concentrate, to which a filler could be added such as cereal grain, sugar, vitamins and minerals. Similar estimates may be carried out if formulations with the other foods are desired. This method of formulating protein-rich foods is, however, not as efficient as that previously proposed, where amino acid supplementation from two protein sources is achieved (25).

RESUMEN

Suplementación, con aminoácidos o proteínas, de la harina de semilla de algodón desgrasada

Con el fin de conocer las deficiencias de la harina de semilla de algodón desgrasada (con 50% de contenido proteínico) y medios de mejorar su calidad nutricional, ésta fue suplementada con aminoácidos sintéticos y otros concentrados proteínicos.

A juzgar por los resultados obtenidos en estudios con ratas, se encontró que la lisina es el primer aminoácido limitante, seguido de la treonina y la metionina. La adición de isoleucina no mejoró la calidad proteínica de la harina de semilla de algodón. Con excepción de la harina de carne, de todos los suplementos proteínicos usados, los de origen animal indujeron una mejoría más efectiva que los de origen vegetal. El concentrado de proteína de pescado demostró ser el mejor de todos, siguiéndole la caseína y la leche descremada. En cuanto a los concentrados de proteína vegetal, aparentemente el de frijol de soya fue igualmente efectivo que el de la levadura torula.

Se comenta el significado de las respuestas obtenidas en los animales con la harina de algodón suplementada, ya sea con aminoácidos o con concentrados proteínicos, a partir de la mejoría de la proteína, lograda tanto en términos de calidad como de cantidad.

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