CCXLII. BIOLOGICAL VALUE OF THE PROTEINS OF CERTAIN CEREALS

By ZOFIA MARKUZE

*From the Laboratory for the Investigation of the Nutritional Value of Foodstuffs,
Biochemical Department, State School of Hygiene, Warsaw, Poland*

(Received 29 September 1937)

THE present research was undertaken with the object of determining the biological value of certain Polish cereals, and of comparing the biological values of wheat proteins from hard and soft grain. In the case of wheat proteins, the effect of milling was also studied by comparing whole grain, meal and flour. The biological value of the proteins was determined by the method of Osborne *et al.* [1919] as in the former studies conducted in this laboratory [Kon & Markuze, 1931; Markuze, 1931; 1934].

EXPERIMENTAL

The following materials were studied: rolled oats, buckwheat groats (whole-meal and milled), barley, millet, semolina and polished rice. In addition, wheat flour, white bread and a few varieties of hard and soft wheat were examined, with the object of ascertaining whether these two types of wheat differ in quality, as well as in quantity, of proteins.

The cereals were ground to a fine powder, and analysed for water and nitrogen. The protein contents, derived by multiplying the N contents by 6.25, are given in Table I, and the compositions of the diets in Table II. The diets were mixed with water and steamed to dextrinize the starch. The rats receiving a fat-free diet were given 2 drops of cod liver oil daily, and diets deficient in the vitamin B complex were supplemented with brewer's yeast extract, in amounts corresponding to 0.2–0.3 g. of dry yeast *per diem* and containing 4.3–6.4 mg. of nitrogen. The experiments were performed on piebald rats from our own colony, and were started when the animals were 3–4 weeks old, and weighed 45–55 g. The actual test period lasted 30 days, and was preceded

Table I. *Crude protein contents of the various substances tested*

Product examined	Protein content (calculated on dry wt.) (% N $\times$ 6.25)
Rollled oats	17.4
Whole buckwheat groats	13.7
Fine buckwheat meal	4.9
Millet meal	13.4
Barley meal	9.8
Semolina	9.7
Polished rice	8.0
Wheat flour	10.5
White wheat bread	10.6
Hard wheat, "Manitoba II"	15.5
Hard wheat, "Garnet"	14.5
Semi-hard wheat, "Ostka Chlopicka"	13.2
Soft wheat, "Dańkowska Graniatka"	10.8

(1973)

Table II. *Compositions of the diets*

All values refer to dry weights

Source of protein	Level of protein intake ...	4.1%†	8.0%	16.2%	Source of protein	Level of protein intake ...	9.9%†
Rolled oats:					Wheat flour:		
Rolled oats	23.0		45.9	95.0	Flour	95.0	
Butter fat	10.0		10.0	—	Butter fat	—	
Salts*	5.0		5.0	5.0	Salts*	5.0	
Rice starch	62.0		39.1	—	Rice starch	—	
Level of protein intake ...	8.4%		13.4%		Level of protein intake ...	10.0%†	
Whole buckwheat groats:					White wheat bread:		
Buckwheat groats	58.3		95.0		Bread	95.0	
Butter fat	10.0		—		Butter fat	—	
Salts*	5.0		5.0		Salts*	5.0	
Rice starch	26.7		—		Rice starch	—	
Level of protein intake ...	4.6%†				Level of protein intake ...	10.1%	
Fine buckwheat meal:					Hard wheat, "Manitoba II":		
Buckwheat meal			95.0		Wheat	64.5	
Butter fat			—		Butter fat	10.0	
Salts*			5.0		Salts*	5.0	
Rice starch			—		Rice starch	20.5	
Level of protein intake ...	8.4%†		12.8%		Level of protein intake ...	10.0%	
Millet meal:					Hard wheat, "Garnet":		
Millet	59.7		95.0		Wheat	69.0	
Butter fat	10.0		—		Butter fat	10.0	
Salts*	5.0		5.0		Salts*	5.0	
Rice starch	25.3		—		Rice starch	16.0	
Level of protein intake ...	9.2%†				Level of protein intake ...	10.1%	
Barley meal:					Semi-hard wheat, "Ostka Chłopicka":		
Barley			95.0		Wheat	75.7	
Butter fat			—		Butter fat	10.0	
Salts*			5.0		Salts*	5.0	
Rice starch			—		Rice starch	9.3	
Level of protein intake ...	7.8%†		9.3%†		Level of protein intake ...	10.6%	
Semolina:					Soft wheat, "Dańkowska Graniatka":		
Semolina	82.4		95.0		Wheat	95.0	
Butter fat	10.0		—		Butter fat	—	
Salts*	5.0		5.0		Salts*	5.0	
Rice starch	2.6		—		Rice starch	—	
Level of protein intake ...	7.6%†						
Polished rice:							
Rice			95.0				
Butter fat			—				
Salts*			5.0				
Rice starch			—				

* Steenbock & Nelson's [1923] salt mixture No. 40.

† These diets were supplemented with brewer's yeast extract.

by a preparatory period lasting about 7 days with the object of accustoming the rats to the diet. The actual test began with the day when the daily ration had to be increased, and the rats were showing a steady gain in weight. The last two columns of Table III give the results of the tests, expressed as the ratio of the increase in weight of the rat to the amount of protein consumed over the 30-day test period.

Table III. *Biological values of the various proteins*

Source of protein in diet	Protein level*	Sex	Gain in wt. g. = a	Total intake		Biological value of protein a : b	Mean
				Food*	Protein* g. = b		
Rolled oats	4.1	♂	15	223.6	9.17	1.64	1.60
		♀	16	245.4	10.06	1.59	
		♂	14	222.0	9.10	1.54	
		♀	18	271.0	11.11	1.62	
	8.0	♂	46	260.2	20.82	2.21	2.22
		♀	34	184.7	14.78	2.30	
		♂	46	273.8	21.90	2.10	
		♀	30	164.0	13.12	2.29	
	16.2	♂	92	344.5	55.81	1.67	1.72
		♀	90	317.4	51.42	1.75	
		♂	98	342.2	55.44	1.77	
		♀	94	340.9	55.23	1.70	
Whole buckwheat groats	8.4	♂	77	336.4	28.26	2.72	2.45
		♀	65	342.2	28.74	2.26	
		♂	60	312.4	26.24	2.29	
		♀	73	345.2	29.00	2.52	
	13.4	♂	107	399.0	53.47	2.00	2.14
		♀	116	388.6	52.07	2.23	
		♂	114	415.5	55.68	2.05	
		♀	103	335.5	44.96	2.29	
Fine buckwheat meal	4.6	♂	38	272.8	12.55	3.03	2.98
		♀	33	252.9	11.63	2.84	
		♂	37	288.9	13.29	2.78	
		♀	41	279.2	12.84	3.19	
Millet meal	8.4	♂	22	237.2	19.92	1.10	0.95
		♀	20	222.2	18.66	1.07	
		♂	13	200.0	16.80	0.77	
		♀	17	230.7	19.34	0.88	
	12.8	♂	30	259.8	33.25	0.90	0.88
		♀	36	304.0	38.91	0.93	
		♂	18	164.1	21.00	0.86	
		♀	23	218.7	28.00	0.82	
Barley meal	9.2	♂	70	411.6	37.87	1.85	1.98
		♀	89	468.9	43.14	2.06	
		♂	64	354.2	32.59	1.96	
		♀	89	467.5	43.01	2.07	
Semolina	9.3	♂	61	364.2	33.87	1.80	1.69
		♀	51	318.3	29.60	1.72	
		♂	59	358.3	33.32	1.78	
		♀	49	316.1	29.40	1.67	
		♂	58	415.0	38.60	1.50	
Polished rice	7.6	♂	40	324.0	24.62	1.62	1.72
		♀	34	255.3	19.40	1.75	
		♂	42	345.0	26.22	1.60	
		♀	37	255.9	19.45	1.90	
Wheat flour	9.9	♂	22	251.4	24.89	0.18	1.02
		♀	25	228.3	22.60	1.11	
		♂	21	238.4	23.60	0.89	
		♀	36	304.8	30.17	1.19	
White wheat bread	10.0	♂	20	222.2	22.22	0.90	0.96
		♀	21	203.9	20.39	1.03	
		♂	19	231.9	23.19	0.82	
		♀	25	227.3	22.73	1.10	

* Calculated on dry weight.

Table III (cont.)

Source of protein in diet	Protein level*	Sex	Gain in wt. g. = a	Total intake		Biological value of protein a : b	Mean
				Food*	Protein* g. = b		
Hard wheat, "Manitoba II"	10.1	♀	51	318.4	32.16	1.59	1.73
		♂	57	331.1	33.44	1.71	
		♂	52	273.3	27.60	1.88	
Hard wheat, "Garnet"	10.0	♀	66	372.0	37.20	1.77	1.84
		♂	58	308.0	30.80	1.88	
		♂	57	306.4	30.64	1.86	
Semi-hard wheat, "Ostka-Chłopicka"	10.1	♀	62	361.3	36.49	1.70	1.67
		♀	55	328.3	33.16	1.66	
		♂	53	320.0	32.32	1.64	
Soft wheat, "Dańkowska Graniatka"	10.6	♀	58	323.3	34.27	1.69	1.66
		♀	62	346.5	36.73	1.69	
		♂	59	344.8	36.55	1.61	

* Calculated on dry weight.

Three protein levels, viz. 4.1, 8 and 16.2 %, were examined in the experiments with rolled oats. The 8 % protein level gave the highest mean biological value (2.22), lower values being obtained at the other two levels.

Wholemeal buckwheat groats, studied at two protein levels, gave a higher biological value (2.45) for the lower level of 8.4 %. The proteins of fine buckwheat meal had an exceptionally high biological value of 3.0; in view of the low protein content of this cereal (4.9 %), only one protein level (4.6 %) was studied.

Barley meal, studied at a protein level of 9.2 %, gave a mean biological value of 2.0, whilst polished rice (protein level 7.6 %) gave a value of 1.7. The lowest biological values were found for millet meal protein, not exceeding unity for protein levels of 8.4 and 12.8 %. This indicates the low nutritional value of millet seed protein.

Semolina, examined at a level of 9.3 %, gave a mean value of 1.7. This value is higher than those obtained by us in an earlier research for white wheat bread proteins and gluten, these approximating to unity.

The effect of the processes involved in the production of bread from wheat grain on the biological value of the protein was studied by comparing the values for whole grain, meal, flour and bread, fed at protein levels of 9–10 %. The results obtained (Table III) indicate that the biological value of whole grain (1.7–1.8) differs little from that of semolina (1.7), but is much greater than for wheat flour and white wheat bread (1.0). This shows that the production of white flour involves the rejection of those parts of the grain which are richest in proteins of high biological value, but that the latter are present in semolina.

A study of the biological values of the proteins of a series of hard and soft wheats,¹ of which the most typical are illustrated in Table III, showed that no clear-cut differences are to be found between the biological values of the proteins of the two varieties.

DISCUSSION

The proteins of all the meals studied, with the exception of millet meal, had high biological values. The highest values were obtained for buckwheat, the result for fine meal being higher than for whole meal.

¹ The author is indebted to Prof. W. Iwanowski, of the Department of Technology of Fermentation and Foodstuffs, Warsaw Polytechnic, for the samples of wheat.

The mean value of 3.0 obtained for fine buckwheat meal protein, at a level of 4.6 %, is much higher than for most other plant proteins and is equal to the value of 3.01 found by Osborne & Mendel [1916] for lactalbumin. The weight increment of 3 g. per g. of consumed protein is the highest so far reported for a vegetable protein, if we exclude the result of Morgan *et al.* [1932] of 3.87 for a residue from extraction of almonds, fed at a protein level of 4.5 % which did not represent a natural mixture of proteins.

The results obtained for cereal proteins indicate the high nutritional value of these products. This is of importance in the study of the nutrition of the poorer classes of Poland, who consume large amounts of meal, as well as in the study of infant foods, in which such products as fine buckwheat meal, semolina, rolled oats and rice represent, apart from milk, the chief sources of protein.

SUMMARY

1. The biological values of the proteins of the most common Polish market cereals have been determined by the method of Osborne *et al.*

2. The highest biological value was found for buckwheat; the values diminished in the order fine buckwheat meal > whole buckwheat groats > rolled oats > barley meal > rice = semolina = whole wheat grain (hard or soft) > wheat flour > millet meal.

The author wishes to express her thanks to Docent Dr G. Szulc for his un-failing and helpful interest in this research.

REFERENCES

- Kon & Markuze (1931). *Biochem. J.* **25**, 1476.
Markuze (1931). *Lek. Wojsk.* **18**, Nos. 3-4.
—— (1934). *Biochem. J.* **28**, 463.
Morgan, Newbecker & Bridge (1932). *Amer. J. Physiol.* **67**, 173.
Osborne & Mendel (1916). *J. biol. Chem.* **26**, 1.
—— & Ferry (1919). *J. biol. Chem.* **37**, 223.
Steenbock & Nelson (1923). *J. biol. Chem.* **56**, 355.