IMPROVING THE BIOLOGICAL VALUE OF BREAD MADE WITH CORN (MAIZE) FLOUR, BY THE ADDITION OF EXTRACTED SUNFLOWER MEAL.

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With 1 Figure and 4 Tables in the Text.
(Received for publication 1st September 1946.)

The addition of corn (maize) flour to wheat bread diminishes its biological value. The diminished value is conspicuous principally from the following standpoints (BEZNÁK 1941):

a) Less amino acid. In wheat there is relatively little tryptophane and lysine (SÓS J. 1942); in zein, the chief protein of corn (maize), tryptophane is entirely lacking.

b) In wheat there is about five times as much nicotinic acid amide as in corn (maize), from which it follows that in corn bread the nicotinic acid content would be decidedly reduced.

c) In corn (maize) there is less mineral substance, notably calcium, than in wheat.

Otherwise in respect to calories corn (maize) bread is about equal to wheat bread. The above reduced values have principally a nutrition biological significance when a people's nourishment is in any case unvarying and incomplete, as in the case of difficult provisionment for city populations in war-time, or in provinces where the consumption of corn (maize) is constant and invaried.

Exception can be taken to the regular consumption of corn (maize) bread from a biological standpoint.

Numerous attempts have been made to improve the biological value of corn bread with the materials at hand in difficult circumstances. These experiments were unsuccessful, either because the materials recommended were still less nourishing than corn itself (as for example millet) (Z. MARKUDZE 1937, BECKER J. 1942) or because the material in

question had a taste disagreeable in bread, as for instance lucerne-flour (see below).

In what follows I report on experiments in the course of which I tried to improve the biological value of corn bread by the addition of extracted sunflower meal. The work falls into three divisions: 1) observations of its appetizingness for human beings; 2.) biological determinations in the growth of white mice; and 3.) chemical analyses.

I.

Determinations in Appetising value.

The observations were made on a group of 30 human adults in the following way: The persons taking part in the experiment received

TABLE I.

Appetising qualities of breads of different ingredients, on the basis of experiments conducted on 30 adult humans. The breads are listed in order of their diminishingly appetising qualities.

List	Ingredients p c.								
	Wheat	Rye	Corn	Barley	Sunfl.	Lucerne	Soya	Yeast	Remarks
1	35	10	35	10	10	—	—	—	20 % potatoes
2	45	—	25	10	20	—	—	—	"
3	30	10	30	10	10	2	6	2	"
4	50	10	20	—	20	—	—	—	—
5	40*	10	20	10	10	2	6	2	
6	30*	10	30	10	15	—	5	—	
7	35	10	20	10	15	4	5	1	"
8	20	10	35	15	20	—	—	—	"
9	20*	10	35	15	10	2	5	3	
10	50	10	20		10	10	—	—	

* whole wheat flour

at a time 10 sorts of bread — the ingredients of which were unknown to them — in slices, 24 hours after the baking. Each kind of bread was then classified according to the 30 decisions as to its appearance and taste. The results of this classification are given in Table I. In this Table we give the ingredients of the different breads and assemble them in accordance with their diminishing appetising qualities.

From the Table it appears that 20% sunflower meal can be added to the bread without appreciably affecting the usual taste. The reason for this is that sunflower meal is nearly tasteless. It was different in the case of lucerne flour, 2 % of which affected the appetising quality

of the bread, 4% of which in the bread brought it to 7th place, and 10 % to the last place on the list. Those taking part in the experiment in fact unanimously declared this latter bread uneatable.

II.

The Biological Experiments.

The biological experiments were conducted on 55 young mice. At the beginning of the experiment the weight of the animals was 8.2/ (± 2.1) g. The mice were put in 5 equal groups. The groups consumed the following foods:

Control group: barley-oats mixture +, for each mouse, 2—2 g.

TABLE II.

Ingredients of breads used in experiments on animals.

The animal groups	Ingredients				
	Wheat g	Corn g	Sunflower g	Potato mash g	NaCl g
I.	2500			600	50
II.		2500		600	50
III.	1250	1250		600	50
IV.	1250	750	500	600	50

of the following mash, cooked fresh each day: 1 part semolina-salt mixture (10 % wheat, 10 % rye, 50% corn (maize), 10 % barley, 50 % soya meal, 5 % casein, 5 % dried yeast, 5 % McCallum-Simmond's salt mixture) + 1.5 parts milk.

The animals of groups I—IV each received bread of different ingredients in a dry state, and as much water as they desired.

The ingredients of the breads investigated in the experiment are shown in Table II.

We measured the mice twice a week and registered the weights. For 30 days, in the tranquillity of their cages, the mice ate the above foods. Beznák and co-workers (1943) have shown that there are some diets on which animals as long as they are in a resting state, show a relatively good growth curve which diminishes when they are made to work, showing that the diet is not complete. Therefore, after these thirty days of quiet, our mice were made to work, in such a way that

at first they ran for 10 minutes, afterwards for 15 minutes a day, at a speed of 7.85 km/hr in a revolving drum.

Figure 1. shows the growth curve of the different groups of animals. The shaded columns on the abscissa represent the time of the running. From the Figure the following can be seen:

The average weight of the group of animals fed on pure corn (maize) bread, after an increase at the beginning lasting 20 days,

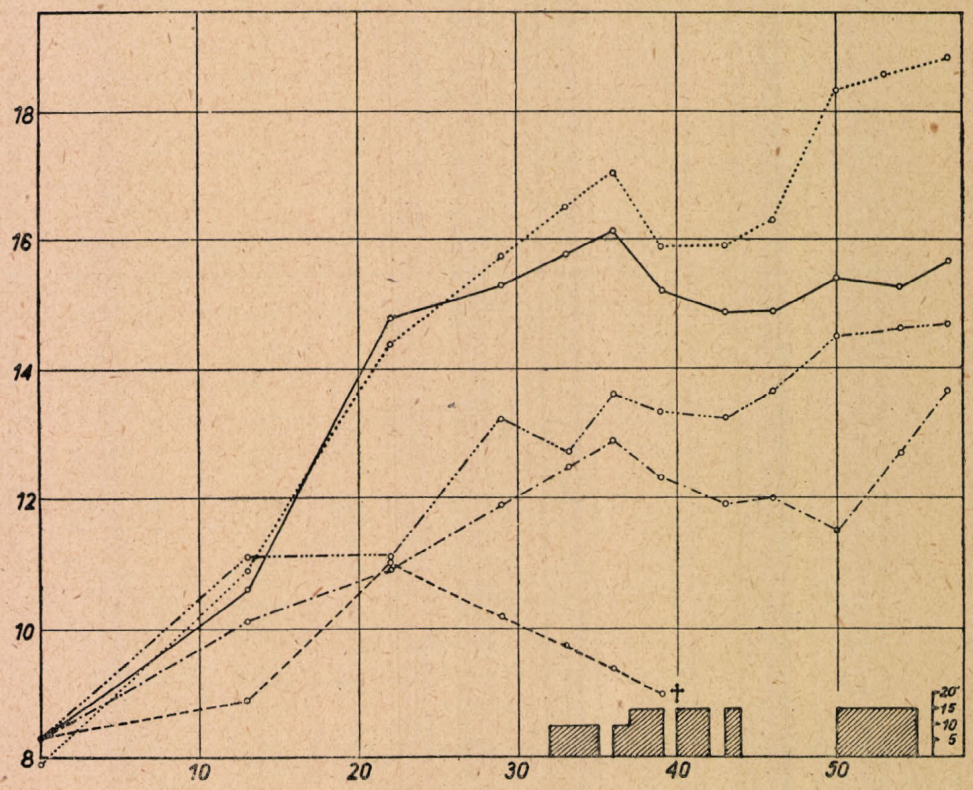

Figure 1. Growth curves of mice consuming different diets. Ordinate: average of weights in grams. Abscissa: time in days.

○.....○ Control group.

○———○ Group consuming bread No. IV (50% wheat flour, 30% corn flour, 20% sunflower meal).

○—...—...○ Group consuming bread No I (wheat flour).

○·—·—·—·○ Group consuming bread No III (50% corn).

○— — — —○ Group consuming bread No II (corn flour). Columns on the abscissa: running in minutes.

began to fall. The running further diminished their weight, and the animals died off, so that by the 8th day of the running period the whole group was dead. Their average body weight when they died was about the same as at the beginning of the experiment.

On pure wheat flour the mice grew, but their speed of growth was slow. During the running, after a slight loss in weight, growth continued at a tranquil, slow pace. By the 60th day of the experiment the growth curve had not yet reached the upper assymptote.

If we substituted corn (maize) for half the amount of wheat in the bread, the animals' growth remained somewhat less than that of animals fed on pure wheat-bread; the mixture was not entirely incomplete, as the growth curve — though low — after a passing drop when the work began, again mounted.

The growth of the group of animals receiving the bread containing 20% sunflower meal, for the first 35 days of the experiment ran almost parallel to the ideal growth of animals consuming a balanced diet. The growth curve was much more precipitous than that of the animals on any of the other breads, showing that the addition of 20% sunflower meal to corn bread is capable of increasing its biological value to a great extent.

During the running the situation changed. The body weight of both groups (control and sunflower) temporarily diminished. But while the mice of the control group, on a balanced diet, afterwards continued to grow at the same speed during the running period, the growth of the animals fed on sunflower meal bread definitely slowed up.

It appears from these experiments that the low biological value of corn bread can be improved by the addition of 20 % sunflower meal, so that it is superior to that of pure wheat bread.

III.

Chemical Analyses.

In the course of the analyses we investigated the following:

The contents of the different kinds of bread in dry materials, crude protein, ash and lime. The sunflower meal was thoroughly analyzed. Besides the above mentioned, we determined the sulphur content of the ash, the tyrosine and tryptophane in the amino acids, as well as the thiamine and the nicotinic acid amide.

METHODS.

a) Dry materials were determined in the usual manner, drying at 110°.

b) Crude protein: total nitrogen (according to KJELDAHL) multiplied by 6.25.

c) Ash: the materials investigated were incinerated in an electric furnace to constant weight.

d) Ca content: The ash got by incineration was dissolved in boiling dilute hydrochloric acid, was filtered, the filtrate neutralized with strong ammonium hydroxide, then again acidified with a few drops of glacial acetic acid. The lime in the solution was determined according to MURER's (1937) method.

e) Sulphur content: The filtered hydrochloric acid solution of the ash was treated with a 1% $BaCl_2$ solution and the resulting $BaSO_4$, after filtering, was burnt and measured.

f) We made the tyrosine and tryptophane determinations in the complete sunflower meal by hydrolyzing with 15% NaOH. The hydrolysis took place in an autoclave at a pressure of 3 atm. for 3 hours (D. DESEÖ 1934). In the hydrolysate the tyrosine was determined according to FOLIN's (1927, 1929) method, by BÁLINT's (1938) modification, the tryptophane after VIRTANEN and LAINE (1936) according to WINKLER (1934) with Stufenphotometer.

g) We applied the thiocrome method by RITSERT (1937) to determine the thiamine.

h) The nicotinic acid amide was determined as follows: The carefully measured air-dried material was boiled for 2 hours in a water bath with 10 times its quantity of n/50 H_2SO_4. The mixture was centrifuged, the precipitate twice again similarly extracted with 5 times as much n/50 sulphuric acid. The combined extract was neutralized with saturated Ba $(OH)_2$, again filled to known capacity and filtered. To 20 ml of the filtrate we added 5 ml M/5 KH_2PO_4 solution and put the reaction mixture in a water bath for 5 minutes, at 75—80°. Then we added 1 ml of fresh-made 5% Cyanogen Bromide solution to it and put it into the same water bath for 5 minutes. (E. BANDIER 1939). After cooling we added 1 ml saturated water aniline solution ,and after about 10 minutes we analysed the developed colour by a Stufenphotomer with S 43. 4/2.0 colour filter (ABDOH u. TÄUFEL 1942). In the control tube was 20 ml of the material examined with a solution of 5 ml hydrophosphate and 2 ml water. In the other control tube we

measured 20 ml distilled water with 5 ml hydrophosphate, 1 ml Cyanogen Bromide solution and 1 ml analine solution. Both control tubes were treated in the same way as the test. From the extinction of the test (E^r) were subtracted the values of the 2 controls (E^c1 and E^c2). The nicotinic acid amide content was calculated by a calibrated curve from the real extinction, $E = E^r - (E^c1 + E^c2)$.

In *Table III* we give some of the more important nutrition biolog-

Table III

Some nutritional factors occurring in extracted sunflower meal, in 85% wheat flour and in corn flour.

	Sunflower meal	Wheat flour	Corn flour
Protein g%	30[1]	8.6[3]	10.0[4]
Fat g%		1.5[3]	2.8[4]
Ash g%	6.4[1]	1.8[4]	0.86[4]
Ca mg%	430.0[1]	24.5[3]	16.0[5]
S mg%	5.7[1]		
Tyrosine mg%	1200.0[1]	900.0[1]	890.0[1]
Tryptophane mg%	250.0[1]	100.0[4]	60.0[6]
Lysine mg%	5.40.0[2]	14.0[4]	166.0[4]
Histidine mg%	4290.0[2]	214.0[4]	97.0[4]
Arginine mg%	2730.0[2]	273.0[4]	280.0[4]
Proline mg%	1580.0[2]	814.0[4]	518.0[4]
Nicotinic acid amide mg%	41.5[1]	5.3[4]	1.2[2]
Thiamine μg%	200.0[1]	110.0[4]	500.0[4]

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ical data of sunflower meal, partly its own analyses, partly on the basis of literary data. For comparison we give the similar data for wheat and corn (maize) flour on the basis of the literature.

From the *Table* it appears that in the extracted sunflower meal

the very materials exist which in wheat or corn are present only in small quantities or not at all, primarily some amino acids (tyrosine, tryptophane. lysine), calcium and nicotinic acid amide. Thiamine was to be found in relatively small concentration in the extracted sunflower meal. The cause of this may be the fact that before the extraction the sunflower seeds were roasted at a high temperature, possibly destroying a greater amount of thiamine which may have been present in the raw seeds.

Table IV. shows the analysis of the different compounds of the breads examined.

From this Table too it appears that the sunflower can supply the lacks in pure wheat, or wheat-corn mixtures. It is interesting that sun-

TABLE IV.

Some nutritional factors occurring in the kinds of bread examined.

Kind of bread*	Water g %	Crude protein g %	Ash g %	Lime mg %
I.	48·1	9.08	1.3	39.8
II.	45.9	5.88	0.9	19.0
III.	48.1	7.62	1.2	28.8
IV.	52.1	9.75	1.4	68.0

* for the ingredients of the different breads see Table II.

flower provides greater water-binding capacity than wheat or corn. There is consequently more water in sunflower bread than in wheat or corn (maize) bread.

Discussion.

From Figure 1 it clearly appears that if we add a quantity of 20 % extracted sunflower meal to wheat-corn bread, its biological value is improved. The mice fed with bread prepared from sunflower meal grew very nearly as well as those on a complete balanced diet. The growth curves also show that the corn bread containing sunflower meal has more value than the bread prepared from pure wheat flour.

The growth of the group of mice fed on bread containing sunflower meal is principally conspicuous during the first period, in the resting state. In this phase of the experiment the sunflower bread seems an entirely adequate diet for the growing mice. But it can be seen that while the sunflower exceeds the wheat and the corn (maize) in biological value it still cannot make the wheat-corn ingredients com-

pletely adequate in the proportions investigated. The second period of the experiment showed this, when the animals undertook physical work. In the beginning, as effect of the work, the body weight of some groups of animals diminished. But while the control mice, on a balanced diet, after the beginning drop in weight quickly regained and again grew at a rapid pace, the growth curve of the mice fed on the bread containing 20% sunflower meal flattened out. Similar effects were observed by BEZNÁK, HAJDU and BEZNÁK (1934) in the case of rats fed on bread mixed with corn-cob flour.

The growth curve otherwise conspicuously showed the pure corn (maize) bread to be incomplete and confirmed the already known fact that an admixture of corn flour to wheat bread diminishes its biological value.

The chemical analyses show the cause for the sunflower meal's being able, in the relatively small quantity examined, decidedly to increase the biological value of the breads prepared from the different cereals. We found (Table IV) that the sunflower meal raises the bread's protein content. Pure wheat bread contains 9.08% crude protein. If we mix corn (maize) flour with it in a proportion of half, the protein content falls to 7.62%. But corn bread containing 20% sunflower meal has 7.5% protein, that is, 7.4% more than the wheat, or 30 % more than the corn bread. Sunflower meal contains, in significant concentration, those amino acids which are lacking in wheat and corn (maize), or occur only in very small quantities (Table III). Thus the sunflower meal not only increases the absolute quantity of nitrogen but also changes the bread's amino acid compounds in a biologically more balanced way.

We remarked in the introduction that corn (maize) has less worth than wheat, principally from the 3 standpoints of: protein amino acid compounds, less mineral substance (principally calcium) and finally because of its inferior nicotinic acid amide content. The lime content of the extracted sunflower meal is really high: 430 mg %; while in wheat bread we find 30.8 mg % calcium, which diminishes to 28.3 mg % when corn (maize) flour is added. We could determine 68.0 mg % Ca ions in the sunflower meal bread, which is higher than in the wheat bread by 72 %, and in the corn bread by 140 %. The sunflower meal is also richer in other minerals than lime and thus the total ash content is higher than that of either wheat or wheat-corn bread.

The low nicotinic acid amide content of corn (maize) bread can be improved by adding sunflower meal. Sunflower meal contains almost as much nicotinic acid amide as dried yeast. This circumstance is significant. It is also known that an incomplete corn meal diet causes pellagra in humans. The cause of this illness is primarily nicotinic acid amide deficiency, but it would seem that the lack of certain amino acids also have a role in its development (Beznák 1941). A small quantity of sunflower meal contains relatively much nicotinic acid amide, lysine and tryptophane, so that with really little sunflower meal added to the diet the occurrence of pellagra could be prevented. But attention must be called to the circumstance that no matter what value a food may have from a biological standpoint, we cannot think of introducing it into a people's diet if the taste is not agreeable, or if from it a food cannot be prepared which meets with the average popular taste. In the first part of the experiment the observations described show that sunflower bread seemed to suit this average popular taste. The taste of sunflower meal itself is neutral and so the taste of the food prepared from it, bread primarily, is not affected.

In sunflower meal, as in corn (maize) flour, there is no gluten. That is why it cannot be added to bread in optional proportions. In the preparation of such foods as are prepared from pure corn meal it can be used, or admixed, in the same way as corn meal or flour. We can put as much of it in bread as experience shows corn flour to be suitable, as much as will give us a well-baked bread. This amount is about 20—30%.

Summary.

1. The observations made on 30 adult humans showed that extracted sunflower meal in a proportion of 20% can be added to wheat flour, or to a mixture of wheat and corn (maize) flours, without spoiling the appetising quality of the bread made from it.

2. Young mice grow the best on a diet of wheat-corn (maize) bread containing 20% sunflower meal, less well on pure wheat, still less well on bread made of wheat-corn (maize) flour. On pure corn (maize) flour bread the animals did not grow and died.

3. The extracted sunflower meal contains such quantities of lime, tyrosine, tryptophane, lysine and nicotinic acid amide that by adding 20% of it to corn (maide) bread its low biological value is improved to such an extent that it is higher than that of pure wheat bread.

4. On the basis of these experiments the introduction of regular

consumption of sunflower meal is recommended in popular diets, principally in regions where pellagra is of common occurrence, and in times of distress when, because of lack of grain, bread is prepared with wheat flour mixed with corn (maize) flour.

The experiments were made possible by a grant from the Hungarian Ministry for Reconstruction, thanks therefore being particulary rendered to Secretary of State, Professor Dr. I. Varga. They were made in part at the Grain and Flour Experiment Station in Budapest, Director F. Gruzl, to whom thanks are also given.

Gratitude is also acknowledged to Miss EMMA MORGEN who assisted in the experiments and to Mrs. J. THOMPSON VASS for the English translation.

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