ON

THE EQUIVALENCY

OF

STARCH AND SUGAR IN FOOD.

BY

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At the Meeting of the British Association held at Belfast, we gave a Paper "On the Composition of Foods in relation to Respiration and the Feeding of Animals," in which it was illustrated, by reference to numerous experiments, that, as our current food-stuffs go, it was the amounts they supplied of the digestible *non*-nitrogenous, rather than those of the nitrogenous constituents, which *cæteris paribus* measured both the quantity consumed by a given weight of animal within a given time, and the amount of increase obtained from a given weight of the dry substance of the food. It was demonstrated too by the results adduced, that much more *fat* might be stored up in the animal body than existed as fatty matter in the food consumed, and it seemed obvious that at any rate the chief source of this *produced* fat must be the starchy and saccharine rather than the nitrogenous constituents of the food. The investigation now to be recorded might, therefore, be considered as closely allied to, or rather in continuation of the former line of inquiry, the point particularly to be illustrated being the comparative respiratory and

Starch, however, there was nearly 20 per cent. of water, instead of only about 6½ per cent. as in the Sugar.

The next Table (III.) shows the daily allowance per head of each of the foods which were given in fixed quantity, and also the amounts consumed of those given *ad libitum*, during each fortnightly period of the experiment, which in all extended over ten weeks.

TABLE III.—Showing the daily allowance, or *ad libitum* consumption, per head, of each food during the five separate periods, and the total period of the experiment.

[Quantities in lbs. and ozs.]

Pens.	Foods—how given.	1st 14 days.	2nd 14 days.	3rd 14 days.	4th 14 days.	5th 14 days.	Average, 10 weeks.
	Lentil-meal.						
1. 2. 3.	In fixed quantity.....	3 0	3 0	3 0	3 8	3 8	3 3¼
4.	*Ad libitum*	4 6¾	2 10	4 4½	4 13	5 11½	4 6
	Bran.						
1. 2. 3.	In fixed quantity.....	1 0	1 0	0 8	0 4	0 4	0 9½
4.	*Ad libitum*	0 6¾	0 4½	0 2½	0 2¼	0 1½	0 3½
	Sugar and Starch.						
1.	*Ad libitum*, Sugar	1 7½	1 10¼	2 1½	2 2¼	1 14½	1 13½
2.	„ Starch	1 10½	1 10¼	2 2¼	2 9	2 11½	2 2¼
3.	„ Sugar	0 14	1 5	1 5	1 11	1 6¾	1 5¾
	„ Starch	0 13¾	1 1½	1 10	1 14½	1 7½	1 6¼
	„ Total	1 11¾	2 6½	2 15	3 9½	2 14¼	2 12
4.	„ Sugar	1 4½	2 9½	2 2½	2 6	2 3	2 2
	„ Starch.....	0 4	0 3¾	0 3¾	0 4½	0 3	0 3¾
	„ Total	1 8½	2 13¼	2 6¼	2 10½	2 6	2 5¾

In pens 1, 2, and 3, then, there was throughout the experiment a fixed and equal daily allowance per head of the lentil-meal and bran respectively. In addition to these, the pigs in pen 1 had as much Sugar, those in pen 2 as much Starch, and those in pen 3 as much, both of Sugar and Starch, as they chose to eat. In pen 4, on the other hand, lentil-meal, bran, sugar and starch were each given in a separate trough, and *ad libitum*; from the consumption in this pen 4, therefore, the natural inclination of the animals for the different foods could be judged of. At the commencement, the allowance of lentil-meal in pens 1, 2, and 3 was 3 lbs. per head per day, this amount being indicated, by previous experiments, as about that which would, with the bran to be added, afford a due supply of the nitrogenous constituents of food. It was at once seen that the pigs in pen 4, which fixed their own consumption of the respective foods, took considerably more of the nitrogenous lentil-meal than

the fixed allowance of the other pens; and after the third period, that is, at the end of six weeks, the fixed allowance of lentil-meal in pens 1, 2, and 3 was increased from 3 lbs. to 3½ lbs. per head per day. In like manner, 1 lb. of bran per head per day was at first given in the pens 1, 2, and 3; but this, on the other hand, was much more than was taken of it by the pigs in pen 4. The fixed daily ration of bran per head was therefore, after the second period, reduced from 1 lb. to ½ lb., and, during the fourth and fifth periods, to ¼ lb. per head per day. Still even this amount of bran was considerably more than that taken at will in pen 4. But one object of the experiment was to give a pretty full allowance of the cheaper and less nutritious bran, in order to see whether, when mixed with pure digestible proximate principles, such as Sugar and Starch, somewhat more of it could, without disadvantage, be employed.

In pen 1, where, in addition to the fixed allowance of lentils and bran, a trough was kept constantly supplied with *Sugar*, it is seen that during the first four periods there was a gradual increase in the quantity of it consumed,—the average consumption for the whole ten weeks being nearly 2 lbs. of Sugar per pig per day. This purely non-nitrogenous substance constituted in fact about one-third of the total food of the animals,—a range of amount, or proportion of the whole consumption, sufficiently great to justify a judgment, by comparison with that of the Starch, of the relative capacities of the two substances to meet the complex demands of the system of a fattening animal.

In pen 2, *Starch* was given as the purely non-nitrogenous and *ad libitum* food; and the average consumption of it over the whole period of ten weeks was rather more than 2 lbs. 2 oz. per head per day. More, therefore, was consumed of the Starch than of the Sugar; but it will presently be seen that the amounts of the *dry substance* of the foods were almost identical in the two cases, and that therefore the apparently larger consumption of Starch was simply dependent on its containing more of water than the Sugar.

In pen 3, in which there was the same fixed allowance of lentils and bran as in pens 1 and 2, the complementary food consisted of both Sugar and Starch. Of these two, taken together, the average daily consumption per head amounted to about 2¾ lbs. Considerably more, therefore, was eaten of the mixture than of either the Sugar or the Starch when given alone. The effect on the appetite of the animal of a certain complexity of diet, even in the case of substances having in one sense equal food capacities, is therefore here illustrated; though, owing probably to a somewhat defective proportion of nitrogenous compounds in the total food of this pen 3, we have not in this case, as will presently be seen, the advantage of this increased consumption in a correspondingly greater proportion of increase to the dry substance of the food consumed.

In pen 4, where the lentil-meal, the bran, the sugar, and the starch were each put into a separate trough, considerably more of the highly nitrogenous lentil-meal was eaten than in any of the other cases. And it is remarkable that, with this larger consumption of lentils, scarcely any free Starch was taken, but of the Sugar more even than in pen 1, where no free starch was allowed, but only the Sugar as the *ad libitum* food. This might be accounted for by supposing that the pigs in pen 4 had a larger and sufficient supply of starch in the larger quantity of lentils taken, and that therefore the system called for the sugar rather than the addition of starch in the free state; and this would be to attribute the result to a physiological requirement, apart from that of the palate or stomach merely. It is, however, much more likely that it was simply a matter of palate and stomach; for in pen 3, where also both

Sugar and Starch were given, a certain portion of each was mixed with the limited food; so that, all except the free Starch being saccharine, the greater would be the relish for it, and hence we have much more of Starch consumed in pen 3 than in pen 4.

But there is another point that should be noticed before leaving the question of the dieting of the animals. In a previous experiment with pigs, in which some of them, which were fed on food comparatively defective in mineral matter, suffered considerably in health, a mixture of coal and wood-ashes, superphosphate of lime, and common salt was given with the best effects. It was thought, therefore, that in this case, in which lentils, sugar, and starch were all somewhat deficient, particularly in phosphates, a similar mixture might be useful. Accordingly a mixture of 20 lbs. of the ashes, 2½ lbs. superphosphate of lime, and 2½ lbs. of common salt were divided into four parts, and one of the fourths given to each pen, this amount being distributed over fourteen days. This mineral mixture was always taken with the greatest avidity and relish—so much so, that the animals would leave their other troughs the moment the fresh supply of this was put within their reach. They were, moreover, upon the whole, very healthy throughout the experiment, and yielded good rates of increase.

In the next Table (IV.) is shown the per-centage proportion to the total food in which each of the separate articles was consumed during the successive periods as the experiment progressed.

TABLE IV.—Per-centage proportion of each food in the total food during each successive period, and the total period of the experiment.

Pens.	Foods—how given.	1st 14 days.	2nd 14 days.	3rd 14 days.	4th 14 days.	5th 14 days.	Average 10 weeks.
	Lentil Meal.						
1.	In fixed quantity.....	54·90	53·16	53·62	59·39	61·89	56·63
2.	„ „	53·05	53·16	53·16	55·37	54·14	53·82
3.	„ „	52·17	46·84	45·32	47·65	52·59	48·82
4.	*Ad libitum*.....	69·14	45·64	62·50	63·12	69·77	62·79
	Bran.						
1.	In fixed quantity.....	18·30	17·72	8·94	4·24	4·42	10·62
2.	„ „	17·68	17·72	8·86	3·95	3·87	10·09
3.	„ „	17·39	15·61	7·55	3·41	3·76	9·15
4.	*Ad libitum*.....	6·69	4·98	2·43	1·87	1·16	3·21
	Sugar and Starch.						
1.	*Ad libitum*, Sugar.....	26·79	29·11	37·45	36·36	33·68	32·74
2.	„ Starch	29·26	29·11	37·97	40·68	41·99	36·08
3.	„ Sugar.....	15·42	20·44	22·66	23·01	21·46	20·79
	„ Starch.....	15·01	17·10	24·46	25·93	22·18	21·23
	„ Total	30·43	37·54	47·12	48·94	43·64	42·02
4.	„ Sugar.....	20·07	45·23	31·60	31·25	26·74	30·51
	„ Starch	4·09	4·15	3·47	3·75	2·33	3·49
	„ Total	24·16	49·38	35·07	35·00	29·07	34·00

Turning first to pen 4, in which all the foods were taken separately and at will, it is seen that the highly nitrogenous lentils constituted a considerably larger proportion of the total food in this pen than in either of the others. The animals first began, *pig-like*, with an excessive quantity, which seems to have amounted for the time to a surfeit; for in the second period they do not take two-thirds as much as in the first, though afterwards they gradually increase to the original amount, but taking then considerably less of the also highly nitrogenous bran than at the commencement. In this pen 4, indeed, the consumption of *bran* is at the commencement only about one-third as great as in the other pens, and it gradually reduces as the experiment proceeds, until at last it amounts to little more than 1 oz. per head per day. Although, therefore, so much more of the nitrogenous lentils is consumed in pen 4 than in either of the others, yet it will afterwards be seen that, taking the lentils and bran together, the proportion of total nitrogenous constituents, in the food of pens 1 and 2 especially, is not so much less than in pen 4 as would at first sight be assumed from the larger consumption of lentils in the latter; and it may be observed that this proportion of nitrogenous compounds was in all the other cases still notably higher than in the cereal grains.

With regard to the more general indications of this Table (IV.), it may be remarked that in former experiments, where fattening animals have been allowed high and low nitrogenous foods separately and at their own discretion, there has been a very marked increase in the proportion of the *non*-nitrogenous constituents consumed as the animals matured. This is not so obvious in the present instance; but in this case the foods were not of an ordinary kind, and were such as to give more scope for the exercise of the instinct of the palate. The result is that those animals which were allowed their own choice of all the foods, took first an excessive amount of the lentils, and then, going to the other extreme, of the Sugar; so that, with this incidental and more than usual interference of the palate with a naturally greedy animal, we have the mere progress of the respiratory requirement and fat-forming tendency of the animals less clearly indicated in the selection of their food according to its ultimate composition.

In Table V. we have the amount of gross food consumed, per 100 lbs. live-weight of animal, per week during each of the successive periods, and the total period of the experiment; also the amount of gross increase obtained by the consumption of 100 lbs. of food during the same periods.

TABLE V.—Showing the rate of the consumption of food, and of the production of increase in weight, during the successive periods of the experiment.

Pens.	Description of the foods.		Average weekly consumption of total food, per 100 lbs. live-weight of animal.					
	In fixed quantity.	*Ad libitum.*	1st period. 14 days.	2nd period. 14 days.	3rd period. 14 days.	4th period. 14 days.	5th period. 14 days.	Average of total period.
1.	Lentils... Bran	Sugar	36·2	3 ·8	27·9	26·6	23·2	29·0
2.	Lentils... Bran.....	Starch ...	37·6	31·9	28·4	28·5	26·5	30·5
3.	Lentils... Bran.....	Sugar .... Starch ...	38·8	36·5	32·9	32·5	26·5	33·0
4.	None.....	Lentils... Bran ..... Sugar .... Starch ...	41·3	31·8	33·1	31·9	30·2	32·6
	Means		38·5	33·0	30·6	29·9	26·6	31·3

Table (continued).

Pens.	Description of the foods.		Gross increase obtained by the consumption of 100 lbs. of total food.					
	In fixed quantity.	*Ad libitum.*	1st period. 14 days.	2nd period. 14 days.	3rd period. 14 days.	4th period. 14 days.	5th period. 14 days.	Average of total period.
1.	Lentils... Bran.....	Sugar ...	26·6	21·9	18·3	19·0	18·5	20·8
2.	Lentils... Bran.....	Starch ...	26·1	20·7	17·3	21·1	14·7	19·9
3.	Lentils... Bran.....	Sugar ... Starch ...	24·8	20·1	19·8	16·2	19·0	19·8
4.	None	Lentils... Bran..... Sugar ... Starch...	25·3	15·8	25·3	19·4	20·6	21·3
	Means.....		25·7	19·6	20·2	18·9	18·2	20·4

Although it has already been seen that a larger amount of food was consumed *per head* as the pigs increased in weight and fatness, yet it is shown in Table V. that there was a gradual decrease in the quantity consumed, *per* 100 *lbs. live-weight of animal,* in all cases from the 1st period to the 5th. In fact, during the short space of five fortnightly periods, the amount of food consumed in proportion to the weights of the animals is pretty uniformly in the four pens about one-third less in the fifth period than in the first. With this decrease in the consumption of food in relation to weight, there is at the same time, as shown in the 2nd division of the table, a considerable decrease in the *amount of gross increase yielded by a given weight of food* as the fattening process progresses. Former experiments have however shown that, as the animal matures, its increase is much less aqueous; so that much of the lessened productiveness of the food in gross increase is only apparent so far as real dry substance of growth is concerned. Indeed, a careful consideration of the results of the Table, taken in connexion with other known facts, leads to the conclusion that the functional expenditure of constituents, so to speak, that is to say, the amount of them required to keep in action the machine of life, though not so great in proportion to the weight of the animal as it matures, yet continues pretty equally so in proportion to the amount of food consumed. On the other hand, the increase attributable to the remainder, or that portion of the food not so expended, though it may be less in *gross* amount than in the earlier stages of feeding, is probably about equal, so far as the storing up of *real dry substance* is concerned. In fact, as the fattening proceeds, less *gross* weight of increase is obtained for a given amount of food; but the quality or food-capacity in its turn of that increase is in a corresponding degree the greater. To fatten therefore beyond the point at which a higher price is obtained for a given weight of meat, is an advantage to the consumer, and not to the producer of it.

In the next Table (VI.) are given the total amounts of each of the fresh foods separately, and the collective foods, and of the dry organic matter, the mineral matter, and the nitrogen contained in them, which were consumed in each pen during the ten weeks of the experiment. There is also given in the last column of the Table the amount of gross increase yielded in each pen.

TABLE VI.—Showing the total amounts of fresh foods, and constituents, consumed, and of increase obtained, during the total period of the experiment.

[Quantities in lbs. and tenths.]

Pens.	Foods—how given.	Gross or fresh food.	Dry organic matter.	Mineral matter.	Nitrogen.	Increase.
	Lentil Meal.					
1. 2. 3.	Fixed quantity—each.....	672	558	28·8	28·3	
4.	*Ad libitum*	918	762	39·3	38·6	
	Bran.					
1. 2. 3.	Fixed quantity—each.....	126	99	7·0	2·9	
4.	*Ad libitum*	47	37	2·7	1·0	
	Sugar or Starch.					
1.	*Ad libitum,* Sugar	388½	360½	3·1	0·7	
2.	,, Starch	450½	360½	1·8	0·7	
3.	,, Sugar	286¼	265½	2·3	0·5	
	,, Starch	292¼	234	1·2	0·5	
	,, Total	578½	499½	3·5	1·0	
4.	,, Sugar	446	414	3·6	0·9	
	,, Starch	51	41	0·2	0·1	
	,, Total	497	455	3·8	1·0	
	Summary.—Total Food and Increase.					
1.	Lentils, Bran and Sugar	1186½	1017½	39·0	31·9	247
2.	,, ,, and Starch	1248½	1017½	37·6	31·9	248
3.	,, ,, Sugar and Starch..	1376½	1156½	39·3	32·2	272
4.	,, ,, ,, ,, ...	1462	1254	45·8	40·6	312

It is a sufficiently remarkable fact, in relation to the main object of this investigation, namely the question of the equivalency of Starch and Sugar in food, that with three pigs in each case, the experiment extending over ten weeks, and the *ad libitum* Starch or Sugar constituting one-third of the total food, we should have, in pens 1 and 2, in the former with Sugar, and in the latter with Starch, absolutely identical amounts of *dry organic substance* consumed in the two cases; and also, within one pound, exactly the same amount of gross increase in weight yielded by it. It thus appears that, whether for the purpose of supporting the functional actions of the body, or of ministering to the formation of increase (for, as will be seen, the rate of increase was in both cases good) these two substances have, weight for weight, values almost absolutely identical. But this point will be better seen in the Tables

which next follow, in which are given, not the *actual* amounts of food or constituents consumed, and of increase obtained, but the amounts of food and constituents consumed *per* 100 *lbs. live-weight*, and the amounts of each which were required *to produce* 100 *lbs. of increase*; and the items which are given in each case are the fresh substance, the gross dry matter, the dry organic matter, the non-nitrogenous substance, the nitrogenous (proteine) compounds, the nitrogen, and the mineral matter,—the latter including only the amounts contained in the respective foods, and excluding therefore that given in the purely mineral mixture.

TABLE VII.—Showing the average amount of total food or constituents consumed, *per* 100 *lbs. live-weight*, *per week*.

[Quantities in lbs., tenths, &c.]

Pens.	Description of the foods.		Fresh food.	Gross dry matter.	Dry organic matter.	*Non*-nitrogenous substance.	Nitrogenous substance.	Nitrogen.	Mineral matter.
	In fixed quantity.	*Ad libitum.*							
1.	Lentils ..... Bran	Sugar	29·0	25·8	24·84	19·93	4·89	0·78	0·96
2.	Lentils .. ... Bran	Starch	30·5	25·7	24·86	19·96	4·90	0·78	0·92
3.	Lentils ..... Bran	Sugar Starch ...	33·0	28·6	27·72	22·88	4·85	0·77	0·94
4.	None	Lentils Bran Sugar Starch ...	32·5	29·0	28·08	22·38	5·70	0·902	1·024
		Means.....	31·2	27·3	26·38	21·29	5·09	0·81	0·96
Mean of 12 previous experiments.			29·5	25·9	24·84	19·15	5·69	0·90	1·12
„ 12 „ „ ...			32·7	27·9	26·80	20·65	6·15	0·97	1·09
„ 5 „ „ ...			32·6	27·0	25·27	19·86	5·42	0·87	1·66

We have then in Table VII. the average amounts, over the whole period of the experiments, of the various constituents consumed weekly, per 100 lbs. live-weight of animal: and at the foot of the Table is given a summary of the same particulars in the cases of three previous series of experiments; in two of which there were 12, and in the third 5 pens. A comparison of the average of these former experiments, in which there was great diversity of fattening food, with that of the present series, sufficiently shows, both how uniform is the average rate of consumption of the dry substance of the food in relation to the weight of the animal when fed under somewhat similar circumstances, and also that the results of the present series, with the food consisting to the amount of one-third of its weight of pure Starch or Sugar, are sufficiently normal in character to be trusted in their indications. And the same may be said in reference to the amount of increase yielded by a given weight of food, as shown by comparing the new results on this point given in Table VIII. with those of the previous ones in the summary at the foot of it.

TABLE VIII.—Showing the average amount of total food or constituents consumed, *to produce* 100 *lbs. of increase*.

[Quantity in lbs. and tenths.]

Pens.	Description of the foods.		Fresh food.	Gross dry matter.	Dry organic matter.	*Non*-nitrogenous substance.	Nitrogenous substance.	Nitrogen.	Mineral matter.
	In fixed quantity.	*Ad libitum.*							
1.	Lentils ..... Bran	Sugar	480	427	411·8	330·5	81·3	12·90	15·85
2.	Lentils ..... Bran	Starch	503	425	410·2	329·2	81·0	12·85	15·25
3.	Lentils ..... Bran	Sugar Starch ...	506	439	425·1	350·6	74·5	11·82	14·51
4.	None	Lentils Bran Sugar Starch ...	468	417	401·8	319·8	82·0	13·01	14·67
		Means.....	489	427	412·2	332·5	79·7	12·65	15·07
Mean of 12 previous experiments.			583	511	488·3	376·3	111·9	17·77	23·20
„ 12 „ „ ...			562	480	461·2	355·9	90·9	16·98	18·93
„ 5 „ „ ...			554	458	429·7	336·6	93·1	15·01	28·77

Looking more closely to the figures in Table VII., it is seen that, excepting in pen 4, the amount of nitrogen or nitrogenous constituents consumed per 100 lbs. live-weight per week was rather less than in the average of former experiments; it was, however, greater than in several of the individual cases of those former experiments, especially where the cereal grains constituted the chief bulk of the food, as has already been alluded to. In fact, although the amount of nitrogen consumed in pens 1, 2, and 3 was less than where the animals took as much of it as they chose to eat, yet even in these cases it was greater than in the very frequent fattening food of the pig, namely, barley-meal, in which, however, the proportion of nitrogen is rather under than over that which is most favourable for the increase of the fattening pig.

Again, in pen 2, with one-third of the total food Starch, about 1½ lb. more fresh food is consumed weekly per 100 lbs. live-weight of the animal than in pen 1, with one-third of it Sugar. But we find that, excluding the moisture in the foods, of which there was more in the Starch than the Sugar, the amounts of *dry organic substance* consumed are absolutely identical in the two cases. It is obvious then that, the animals having in the two pens only about two-thirds as much material in their lentils and bran as the wants of the system called for, the further demand, amounting to one-half more, or one-third of the total food, was fulfilled in the respective cases by identical amounts of the dry substance of the Sugar and the Starch. These then are practically identical in their capacity of meeting the mixed wants of the animal body for non-nitrogenous substance. In pen 3, the weekly consumption of *non*-nitrogenous substance per 100 lbs. live-weight is rather greater

than in pens 1 and 2; and it is probable that, both Sugar and Starch being allowed in this pen, the greater variety of food increased the appetite. There was also with this greater consumption of *non*-nitrogenous substance more both of actual increase of animal, and of increase for a given weight of *nitrogenous* substance consumed, though somewhat less of it in proportion both to the *non*-nitrogenous substance and to the total dry organic substance of the food. It may likewise be said of pen 4, that, with greater variety in the food, more was eaten in relation to the weight of the animal. But in this case there was more of the *nitrogenous* as well as of the non-nitrogenous constituents consumed; and with this larger and probably more normal proportion of the latter to the former, we have, as is seen in the next Table (VIII.), a better proportion of gross increase both to the non-nitrogenous substance and to the total organic substance consumed.

But the amount of food consumed to a given weight of animal, as shown in Table VII., represents of course, not only the demands for the maintenance of the animal machine, that is, of the respiratory and collateral functions, but also those for the growth and permanent increase of the body. So also in Table VIII., the average amount of foods consumed for the production of 100 lbs. of increase includes also those required for the respiratory and other functional purposes. In our former Paper, however, read at Belfast, it was shown that, in the case of a fattening pig then referred to, only about 15 per cent. of the dry substance of the food consumed was stored up in the animal as non-aqueous increase—about 85 per cent. of the total dry substance of the food of the animal being therefore expired, perspired, or voided. Although, however, so small a proportion of the food consumed may be actually stored up in the animal, still a comparison of the amounts of gross food or constituents consumed to produce a given weight of increase is doubtless of much importance as a measure of the relative feeding-qualities of different articles of diet; and this is the point illustrated in Table VIII.

In this Table (VIII.), comparing first together the results of pens 1 and 2, we find that not only, as has been already seen, was the rate of consumption of the dry organic substance of the Starch and Sugar exactly identical in relation to the weight of the animal, but here it is found that the amounts required to yield a given increase in the weight of the body are also exactly identical; for 411¾ lbs. of total dry substance were required to produce 100 lbs. of increase when one-third of the food was Sugar, and 410¼ lbs. when one-third of it was Starch. The equivalency of the two would seem therefore to be clearly proved, both for the purpose of the maintenance of the system, and for that of the increase of the body, of a fattening animal. Against the above quoted amounts of dry substance required in these cases to produce 100 lbs. of increase, it required 425 lbs. in pen 3, where the allowance of nitrogenous constituents was about the same as in pens 1 and 2, but the proportion of non-nitrogenous constituents eaten was rather greater; and only about 402 lbs. were required in pen 4, where the consumption of nitrogenous constituents was somewhat greater than in the other cases. Whilst, therefore, as we have shown in other papers, as our current food-stuffs go, it is frequently their *non*-nitrogenous rather than their nitrogenous constituents which measure their combined respiratory and feeding-capacities, yet we have here usefully indicated, as also in other cases, the point below which a lessened amount of nitrogenous constituents is disadvantageous.

In conclusion, the evidence of direct experiment clearly goes to show that all but identical amounts of the dry substance of Cane-Sugar and of Starch are both consumed by a given weight of animal within a given time, and are required to yield a given weight of increase. The practical identity

in feeding-value, which from the known chemical relationship of these two substances has hitherto been assumed, is now therefore experimentally illustrated, and it probably only varies in point of fact with their slightly varying per-centages of carbon.

If, then, Cane-Sugar has no higher feeding-capacity than Starch, the relative prices, weight for weight, of the sugar, duty free, and of the starchy grains generally used for feeding-purposes, will afford an easy means of estimating, the probable economy of the use of the former. At the price, including duty, of the coarse Penang sugar used in the experiments, it would cost three or four times as much as the starchy cereal grains at the present time; and it should be remembered that these would also supply a considerable amount of the needed nitrogenous constituents of food.

These new results too, as far as they can be supposed to apply with numerical accuracy, considering the difference between cane-sugar and the saccharine matter of malt, are consistent with direct experiments which we published some time since on the comparative feeding-values of malted and unmalted grain. Thus, it was shown that the dry substance of malted and unmalted barley had very nearly equal respiratory and feeding-capacities. But, not only is the process of malting attended with considerable expense, but it was shown in the experiments alluded to, that during the process there was a loss of 6 per cent. of the gross dry substance of the barley, and of 4 per cent. of its total nitrogen, even when the malt-dust was included as a product of the process, and supposed to be equally valuable as food; whilst, if the malt-dust were excluded, the loss for feeding-purposes of the dry organic substance of the barley was 10 per cent., and that of its nitrogen 13½ per cent. It might be true that malt and other saccharine matters might serve in some degree to give a relish to the food, and thus induce the animals to eat more, which in "fattening" is always a consideration; but this incidental benefit could not counterbalance much increased cost. Indeed the general result of experiment is contrary to the conclusion that any extensive use of malt for feeding-purposes would be such a boon as has been supposed.

The proved practical equivalency of Starch and Sugar in food is also of interest, as has already been alluded to, in reference to some other of the conclusions to which we have arrived in former papers. Thus, it has been shown that a fattening animal assimilates much less nitrogen than has usually been estimated; and further, that it may store up very considerably more fat than exists ready-formed in its food; whilst, again, this *produced* fat is doubtless in a great measure formed from the *starchy* and *saccharine* substances which constitute so large a proportion of the *non*-nitrogenous constituents of our staple vegetable foods. It is these *starchy* and *saccharine* substances, too, which in practice serve largely to meet the requirements of the respiratory function; and this it has been shown it is that, under ordinary circumstances, constitutes, to such an extent, the measure of the amount of the food demanded by the animal system.