

Biological Utilization of Protein as Influenced by Dietary Carbohydrates

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Introduction

The response of an organism to a particular protein has been shown to depend upon the nature of the carbohydrate in the diet (Guggenheim et al., 1960; Dahlquist & Thomson, 1964). Several investigators have demonstrated that most of the carbohydrates are superior to simple sugar in tests such as growth rate, protein efficiency ratio, and nitrogen balance (Harper & Katayama, 1953; Womack et al., 1953; Khan & Bender, 1974; Khan, 1975). This has been attributed to slower rates of digestion and absorption along the gastrointestinal tract, resulting in more efficient utilization of protein. A rapid passage of the diet through the intestine may impair not only the digestion of the dietary protein but also that of the metabolic secretions, leading to severe nitrogen losses (Harper et al., 1952). Other workers, however, have failed to demonstrate this effect (Spivey et al., 1958; Chang, 1962; Eggum & Christensen, 1974). True digestibility and biological value were unaffected by the carbohydrate source (Wiener et al., 1963).

In most of the above experiments, the effect of either starch or sucrose as a dietary carbohydrate on the utilization of protein has been studied. As both types of carbohydrates are commonly consumed together in daily human diets, simultaneously, there is a gradual change from starch to sucrose as major source of energy and this may have a different effect on the utilization of dietary protein. A study was thus planned to investigate the effect of starch and its replacement by increasing amounts of sucrose on the utilization of protein by weanling rats.

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Materials and Methods

Animals and diets

Forty-eight weanling Albino rats, 23 days old, were used for the biological evaluation of dietary protein. The rats were given stock diet (20% protein) for 7 days and were divided randomly into twelve groups of 4 rats each. The experimental diets (Table 1) containing 10% protein were randomly assigned to these groups in such a way that each diet was fed to two groups of rats for a period of 10 days. A protein-free diet (F) was included in the test to measure metabolic faecal nitrogen. However, corrections for metabolic and endogenous nitrogen losses due to starch and sucrose were not made in the present work.

Procedure

Each group of rats was housed in a cage with a screen mesh floor. Food and water were given ad libitum. A sheet of filter paper was placed under each cage for the collection of faeces. The body weight of each group was recorded at the start of the experiment and thereafter daily at the same time of the day. Feed consumption was measured after 10 days. PER (g weight gain/g protein consumed) was calculated. At the end of the experiment the rats were killed with chloroform. Incisions were made into the skull, thoracic and abdominal cavities, and carcasses of each group were dried to a constant weight at 105°C. Dried carcasses were weighed and ground by passing through an electric grinder. The nitrogen contents of diets, faeces and carcasses of each group were determined by a Kjeldahl method. Net protein utilization was estimated according to the method of Miller & Bender (1955). The true digestibility and biological value of the diets were calculated as follows:

Table 1. Composition of experimental diets (%)

Ingredients	Diets					
	A	B	C	D	E	F
Corn starch	76.0	57.0	38.0	19.0	—	42.0
Sucrose	—	19.0	38.0	57.0	76.0	42.0
Casein	12.5	12.5	12.5	12.5	12.5	—
Corn oil	5.5	5.5	5.5	5.5	5.5	10.0
Vitamin mixture	2.0	2.0	2.0	2.0	2.0	2.0
Mineral mixture	4.0	4.0	4.0	4.0	4.0	4.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
<i>Carbohydrate distribution (%)</i>						
Corn starch 100	—	75	50	25	—	—
Sucrose	—	25	50	75	100	—

$$TD(\%) = \frac{[\text{Nitrogen intake} - (\text{faecal nitrogen} - \text{metabolic nitrogen})]}{\text{Nitrogen intake}} \times 100$$

$$BV(\%) = \frac{\text{Net protein utilization}}{\text{True digestibility}} \times 100$$

The data were subjected to statistical analysis by using analysis of variance technique (Snedecor, 1965).

Results

The data in Table 2 indicate the average values for weight gain, protein efficiency ratio, true digestibility, net protein utilisation and biological value.

Body weights

The rats gained 117 g on the starch based diet. A 5.9% lower weight gain was observed when starch was replaced by 25% sucrose as a source

of dietary carbohydrate, but the difference was not statistically significant. However, a further reduction ($P < 0.01$) in the growth rates was noted with increasing levels of sucrose in the diets and was 29, 40 and 56% on diets in which corn starch was replaced by 50, 75 and 100% sucrose respectively.

Protein efficiency ratio (PER)

Since the standard PER test is 28 days, PER values calculated from 10 days' feeding may not be the same values as the standard PER values. The PER for starch based diet was 3.4 and decreased 11.8, 22.0, 35.3 and 59.9%, respectively, when 25, 50, 75 and 100% starch was replaced by sucrose in the diets. There was no significant difference between the PER values of diets containing starch alone or replaced by 25% sucrose as a source of dietary carbohydrates, though both the diets were significantly better than diets in which 50, 75, and 100% starch was replaced by sucrose.

True digestibility (TD)

TD was not affected by the type of dietary carbohydrates as there was no significant difference between the values for true digestibilities of the diets having various combinations of corn starch and sucrose.

Net protein utilization (NPU)

The percentage of nitrogen intakes, retained in the body of the rats having corn starch or sucrose as a source of carbohydrates in the diets was 74.5 or 63.0 respectively, and the difference between the two was statistically significant ($P < 0.01$). NPU was only slightly reduced when 25% corn starch was replaced by sucrose in the diet, whereas a significant fall in NPU values was observed when 50, 75 and 100% corn starch

Table 2. Biological utilization of protein as affected by corn starch and sucrose as a source of dietary carbohydrates

	Carbohydrates source				
	Starch 100	Starch-Sucrose 75:25	Starch-Sucrose 50:50	Starch-Sucrose 25:75	Sucrose 100
Weight gain/group (g)	117.0	110.0	83.0	70.0	51.0
Protein efficiency ratio	3.4	3.0	2.7	2.2	1.5
True digestibility (%)	96.5	96.5	95.5	96.5	95.5
Net protein utilization (%)	74.5	73.5	69.5	66.5	63.0
Biological value (%)	77.0	76.0	73.0	69.0	66.0

was replaced by sucrose in the diets as a source of dietary carbohydrates.

Biological value (BV)

The BV, a derived factor which indicates the percentage of absorbed nitrogen, retained in the body was high (77%) for the starch-based diet. The BV decreased with the increasing levels of sucrose in the diet. The percentage decrease was 1.3, 5.2, 10.4 and 14.2, respectively, when 25, 50, 75 and 100% starch in the diet was replaced by sucrose. The BV for the experimental diets was of the same order as NPU.

Discussion

Present results show that corn starch as a sole source of carbohydrate gave better growth and protein utilization than sucrose and confirm the findings of the previous work, where the possible explanations were discussed (Khan & Bender, 1974; Khan, 1975). There was no significant change in body weight and the utilization of protein when 25% corn starch in the diet was replaced by sucrose; these findings are partly in line with Eggum & Christensen (1974), but both the body weights and protein quality were affected by the increasing amounts of sucrose in the diets. It appears that sucrose at the level of 25% of carbohydrate in the diet does not impair the digestion of protein, metabolic secretions and absorption of amino acids from the gastro-intestinal tract and has no significant adverse effect on the utilization of protein. Furthermore, it is evident that corn starch or sucrose alone, or in various combinations, as a source of dietary carbohydrates, did not affect the true digestibility of the protein and is in agreement with the findings of Chang (1962), and Spivey et al. (1958).

Summary

Biological utilization of protein at a level of 10% in the diet as affected by corn starch alone or replaced by 25, 50, 75 and 100% sucrose as a source of dietary carbohydrate was studied. Corn starch alone was superior to sucrose in tests such as growth rate, protein efficiency ratio, net protein utilization and biological value. A decrease in the nutritive value of protein was observed with increasing levels of sucrose in the

diet, though replacement of starch by 25% sucrose had no significant effect on the biological utilization of protein. True digestibility was not affected by the different types of dietary carbohydrates. It is suggested that sucrose at a level of 25% of the carbohydrate in the diet does not impair the digestion of protein, metabolic secretions, or absorption of amino acids from the gastrointestinal tract, hence resulting in comparable growth and protein utilization to that of corn starch based diet.

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