LACTOSE: ONE OF NATURE'S PARADOXES

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(Received for publication June 25, 1971)

Abstract

Lactose is the major carbohydrate of mammalian milk but its concentration in milks from different species varies considerably. Dietary lactose is responsible for a number of ill-effects in many species including man, both in normal and abnormal conditions of the organism. Although etiologically perplexing, certain distinct nutritional advantages have been attributed to lactose, and technologically we already know how to harness its properties to advantage.

Lactose, or milk sugar, is practically speaking the only carbohydrate in cow's milk and constitutes 4 to 5% of the total weight of the milk. The amount of lactose in milk varies from species to species and reaches levels between 6 and 7% in human milk. This is not in itself nutritionally advantageous, however, because the ability to digest lactose properly varies, not only among different mammalian species, but also among different human races.

Lactose in Foods

Lactose is not a very sweet sugar, always tastes very gritty, and won't dissolve very well. In some of our foods these properties are harnessed to useful advantage. The texture of sweetened condensed milk depends on exactly the right amount of lactose being present. Too much can cause a sandy feeling in the mouth and too little will result in a slimy product. Lactose interacts with milk protein when heated to form brown colored substances. This is useful in toffee manufacture but can be a nuisance in dried milk manufacture, when heat has to be applied in the process. Generally, all those technological difficulties make purification and use of lactose uneconomical and each year, therefore, thousands of tons of waste liquor from dairies are dumped into the sea. Whey contains a lot of lactose, but it is not normally wasted. After concentrating in evaporators, creameries sell it for use in confectionery or pharmaceutical products, or in cruder preparations for animal feeds.

Physiological Characteristics of Lactose

If we want to know why lactose differs from other sugars we must examine it, first at the molecular level and then in terms of its biochemical functions. Molecules of lactose are formed out of galactose joined by a β-D-(1→4) linkage to glucose and before we can absorb milk sugar it must be hydrolyzed in the brush border region of the small intestine, to glucose and galactose, by lactase. The subsequent fates of the glucose and galactose depend on a number of utilizable metabolic pathways and galactose does exist as a permanent feature of many tissues. Brain cells for example contain galactose joined to other groupings, and indeed the brain would not be able to function properly without its galactose. However, it is by no means certain that we need to eat lactose or galactose for this purpose, and probably our bodies convert all the galactose which we absorb into glucose. Galactose is then resynthesized out of glucose whenever it is neded for nervous tissue.

Lactose in Milk

The milk of mammals contains all the essential vitamins, minerals, fats, and proteins which are needed for healthy living. What is not clear, however, is why the milk of so many species should contain over 4% of carbohydrate. More particularly, why should it be lactose?

If we look more carefully at the composition of milk in the different mammalian species we find that there is considerable variation in lactose content not only between species, but also between individuals. Furthermore, although only a limited amount of research has so far gone into it there is also a considerable variation in the amount of the enzyme lactase in the intestine of individuals (7). There may possibly be a relationship between the lactose content of the milk and the lactase content of the intestine. In the California Sea Lion, for example, whose milk contains no lactose, there is no intestinal lactase.

Problems When Milk is Consumed

During the past decade it has become clear that the majority of the world's adult population cannot very easily drink milk and this may be caused by the absence of the enzyme lactase in their intestines, so that they cannot digest lactose. As a result adults who drink milk develop cramping pains, sometimes within minutes of drinking the milk, followed frequently by flatulence and diarrhea (2). In several surveys 70 - 90% of adult Africans, Thais, Chinese, and other Oriental races were found to suffer from

the complaints, which are typical of many rare food sugars *(1)*. In such individuals the unhydrolyzable lactose (or other sugar) draws water osmotically from the walls of the intestine, and is attacked by gut microflora producing acids. Fortunately for most of us in the U.K. and U.S.A. only 5 - 10% of the population or less suffer in the same way. Why should this racial difference exist? The answer is still obscure and scientists are divided in their opinion over whether the difference is genetic or environmental. In other words either we inherit the ability to digest lactose normally, or we may develop the inability to do so by failing to drink enough milk after weaning, so that the level of the enzyme lactase decreases in the intestine.

Babies and children may also suffer from the same type of symptoms after drinking milk and the collective syndrome is referred to specifically as *lactose intolerance*. In surveys among Bantu populations doctors have fed lactose to children and produced very violent intestinal disturbances, so that in some instances death has resulted following the tests *(5)*.

Another way of proving lactose intolerance is to feed lactose to the patient and subsequently to take blood tests every few minutes for the next hour. If the blood sugar level rises normally, as after the ingestion of sucrose, the patient is normal. If, however, the blood sugar level does not rise, this means that the patient is lactose intolerant. Consequently the lactose in the intestine is not digested, bacteria will attack it, and all the usual symptoms of cramping pains, flatulence, and diarrhea will result.

Lactose intolerance is encountered all over the world, but a rarer and much more deadly disease is galactosaemia. This disease is inherited but only affects about one baby out of 40,000 due to the lack of the enzyme glucose 1-phosphate: galactose 1-phosphate uridyl transferase. Galactose builds up in the liver (as its phosphate) because it cannot be converted to glucose, and the babies become very ill and frequently die *(11)*.

Almost all surviving galactosaemics are mentally retarded and the only way to treat the disease known to doctors is to recognize it quickly and remove all galactose and lactose from the babies' diet. Obviously, since babies drink only milk, we cannot do this without special dietary preparations being made available in the hospitals to meet such emergencies. Fortunately food manufacturers in the developed countries are already able to produce substitute milk powders sweetened with substances such as corn sugars or fructose. There are several products of this type now available *(6)* and the demand for similar commodities tailored for clinical purposes will probably increase in the future. A typical preparation for use in cases of galactosaemia, lactose intolerance, or gastroenteritis is shown in Table 1, but these substitute milks are not complete foods and should therefore only be used under medical supervision.

TABLE 1. COMPOSITION OF SUBSTITUTE MILK POWDERS

Approximate analysis	Dry food (g per 100g)
Vegetable fat	22.3
Unhydrogenated cocount oil	15.0
Unhydrogenated maize oil	7.3
Protein (washed casein)	22.3
Carbohydrates (liquid glucose)	50.2
Mineral salts	3.0
Moisture	2.0
Calcium	0.720
Phosphorus	0.480
Lactose (approx.)	0.098
Meso-inositol	0.313
Choline chloride	0.067
Calories	503

As well as the inability of some humans to digest lactose properly there are several known cases of animal species which are also unable to tolerate milk sugar in quantity as a nutrient. If weanling rats, for example, are fed lactose at a level of 30% of their diet, in addition to diarrhea they rapidly (within a few days) develop cataract *(8)* or opacity of the lens of the eye. This must result from the galactose part of the lactose, because if rats are fed either galactose or human milk alone, they also develop cataract, but they do not if they are fed glucose alone. Galactose-cataract formation in rats is not reversible. A more alarming experiment along these same lines has recently been carried out at the Johns Hopkins Hospital, Baltimore *(9)*. Every single member of a colony of rats fed yogurt as an exclusive diet developed cataract. Evidently galactose, part of the lactose structure, constitutes 22 to 24% of the caloric value of yogurt. Chicks also develop a peculiar syndrome if they are fed galactose or lactose, which is characterized by shivering and shaking and general debilitation *(10)*.

FURTHER USES FOR LACTOSE

Since some human beings cannot tolerate lactose as a food we are left with the problem of harnessing some of the lactose which we produce for some other useful purpose. One which has already been discovered is to use it as a fermenting medium for penicillin production, as the sugar is fermented slowly and conveniently by penicillin moulds.

It must not be thought that because lactose has certain drawbacks for some human beings that the majority of us in the western world cannot enjoy it as a normal food component. It is clearly of great use as a health food in special diets when decreased

sweetness is required and some have claimed that diabetics can tolerate lactose levels far in excess of what might be expected compared with sucrose or glucose. Some accepted diabetic ice-creams have relatively large levels of lactose. In normal health lactose may exert considerable nutritional benefit in the diet. In a recent experiment it was shown that when lactose was ingested by normal adult volunteers the fecal and urinary calcium and phosphorus fell, with a striking improvement in calcium and phosphorus balance. In lactose intolerant patients no such improvement in mineral balance occurred *(4)*.

In most food products lactose probably exists as milk or milk products rather than as the refined sugar. Lactose is a large component of dry coffee cream preparations, for example, and concentrated whey is used in many of our chewy confections. Whey lactose interacts with the milk protein, casein, and on heating, brown substances are formed with attractive flavors that are essential ingredients in toffee making *(3)*. Sogginess in pie crusts can be reduced by applying a lactose solution wash to the surface before baking. Potato chips and French-fried potatoes can be given a deeper, more uniform golden color if they are dipped into a lactose solution before cooking in deep fat. For more of us lactose taken as a normal balanced constituent of milk products in our diet is probably a beneficial nutrient, encouraging us not to hunt for immoderate levels of sweetness which may result in obesity and related dietary problems. Probably the racial differences in regard to lactose intake described in this paper reflect acquired dietary needs, resulting from generations of national food preferences. Provided that we take care to note any physiological disorders recurring after a particular food intake and seek medical advice where necessary, we may with some safety, accept the old adage 'a little of what you like is good for you.' As in many other aspects of our diet it appears that Nature has deliberately concealed her purpose in providing lactose as the milk sugar of so many different species. We must be careful how we use it, so that we may be sure its applications can be extended further.

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corrections, or suspension of the operator's permit in flagrant cases of non-compliance.

Grading and public placarding or public posting of inspection results, is grossly unfair to the business establishment—especially when it becomes a substitute for adequate counseling, inspections and application of enforcement procedures.

The customer certainly has a right to expect that the foodservice operator and health department are both doing their job with respect to the protection of the customer from contaminated food and possible foodborne illness. The customer should not have to face a posting of sanitation deficiencies as a prelude to enjoying a meal in a given establishment. It would be unreasonable and unfair to offend the sensibilities of the customer and to jeopardize the business success of all establishments by requiring the posting of inspection sheets or the frequently-misunderstood A-B-C-rating placards.

The NRA, speaking for its combined membership of foodservice industry leaders, reaffirms its basic policy, which is:

A. To safeguard the health and welfare of its patrons in providing the best in foodservice.

B. To see that food is prepared under the highest standards of sanitary handling and,

C. To guarantee that meals will be served under conditions and in surroundings maintained with such constant supervision as assures service of food in attractive, sparkling clean establishments.

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