Primary Adult Lactose Intolerance in the Kivu Lake Area: Rwanda and the Bushi

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In order to investigate the ethnic differences of lactose intolerance in the Bantu and Hamitic races, lactose loading tests were performed on the populations living around Kivu Lake in central Africa. In addition to the blood sugar rise the identification of the urinary sugars after the loading test was found to be a useful criterion for the diagnosis of lactose intolerance. Two out of 27 Tutsi (7.8%), 21 out of 36 Hutu (58%), 17 out of 22 Twa (77%), and 27 out of 28 Shi (96%) were lactose intolerant. These frequencies are not linked with the actual milk-drinking habits. Of 3 Twa families, 2 were mostly lactose intolerant, whereas the third was predominantly tolerant. For 11 mixed-bred Hutu-Tutsi the frequency of lactose intolerance was 55%. The results are in favor of a genetic origin of lactose intolerance.

Intestinal lactase (β-galactosidase), necessary for the breakdown and absorption of lactose, declines to a low or even zero level at the age of 3 to 4 years in most non-Caucasian adults. With lactase-deficient persons an oral lactose loading test produces a flat blood sugar curve and often causes diarrhea and abdominal flatulence (1), which is commonly designated as lactose intolerance.

Primary adult lactose intolerance, also called adult lactose intolerance or malabsorption, has a rather low incidence in Caucasians: 19% in American Whites (2, 3), 18% in Fins (4), and 2% in Danes (5).

In America, lactose intolerance of varying degrees (70–95%) has now been reported in American Indians (6), Mexicans (7), Peruvians (8), Eskimos (6), and Negroes (see below). In Asia, high levels of lactose intolerance have been mentioned in Thais (9), Chinese (10), Malays (11), Indians and Pakistanis (12), Arabs (13), and Jews (14). Australian aborigines (15) and natives of New Guinea (16) are generally lactose intolerant. In Europe, lactose intolerance is only prevalent in Greeks and Cypriots (17) and in southern Italians (18).

The Negro race, which is of particular interest in this study, is also predominantly lactose intolerant. Cuatrecasas et al (19) and Paige et al (20) reported intolerance in about 70% of the Negroes of the United States. An investigation of the Negroid race of Curaçao revealed that all 35 subjects were lactose intolerant (21). In Surinam the Bush Negroes are all intolerant to lactose, as are also 90% of the Creoles (22). More particularly in Africa, Cook and Kajubi (23) described intolerance in 90% of 52 hospital inmates belonging to the Baganda tribe of Uganda, which is of Bantu origin, compared with only 17% of 12 Tutsi and 9% of 11 Hima hospital inmates, both of Hamitic origin. Jersky and Kinsley (24) reported lactose intolerance in 90% of 38 healthy South African Bantus. In Nigeria, 98% of 41 Yoruba and Ibo, 76% of 17 Haussa, 70% of 24 town Fulani, and 20% of 9 nomad Fulani are lactose intolerant, all of the subjects being healthy (25). In Kenya, 62% of

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45 Negro children malabsorb lactose (26). Elliott et al (27) reported lactose intolerance in 95% of 52 healthy Bantu adults of the Zaire republic and in none of 15 Tutsi, who emigrated from Rwanda and Burundi. Nine persons originating from southern Sudan and 6 subjects from Cameroon were found to be lactose intolerant.

The striking contrast between the lactose intolerance of the Bantu and the tolerance of the Tutsi populations prompted us to undertake a systematic investigation in the Rwanda, where these different ethnic groups have lived in close relation for several centuries. We have also included a survey on the Shi tribe which dwells in the eastern province of the Zaire Republic adjacent to Rwanda, because of their ethnic and social organization is very similar to that of the Rwanda populations. The results of the present investigation have been related to the cultural history of cattle raising and milk intake.

ETHNIC HISTORY OF RWANDA AND BUSHI

Rwanda

The actual population of Rwanda belongs to three major ethnic groups: the Twa represent about 1% of the population, the Hutu 83%, and the Tutsi 16%. The Twa, who according to oral traditions are the oldest habitants of Rwanda, are forest dwellers and anthropometrically related to the pygmy race. The Hutu, who settled down in the country as early as the 13th century, are agriculturalists of Bantu origin. The Tutsi began to infiltrate in the 14th century and gradually built up a powerful kingdom in the 17th century. They are of Hamitic racial origin and introduced the habit of cattle raising and milk drinking in Rwanda (28).

Soon after their immigration, the Tutsi built up a feudal system (*ubuhaké*) with composite clans. The 18 major clans of Rwanda must be considered to have been in their initial phase socioeconomic entities, composed of the dominant Tutsi and the Hutu and Twa subjects. Within the composite clans, however, the three ethnic groups remained separated from each other according to an endogameous caste system. The three castes were hierarchically structured according to a differentiation of labor based upon ethnic origin. Although marriages were normally limited to members of the same caste (i.e., ethnic group), occasional intermarriages or unions of the ruling Tutsi with the Hutu and, to a lesser extent, with the Twa could occur (29).

In this culture, where the social position was determined by the importance of the cattle herd, only the pastoral Tutsi nourished themselves principally with fresh milk. Agricultural and forest products constituted the basic food of the Hutu and the Twa, respectively (29). The recent acculturation has made the situation such that nowadays the milk-drinking habits are less strictly related to ethnic origin.

Bushi

The Shi occupy a territory situated west and southwest of Kivu Lake, including the provincial town Bukavu, and are commonly referred to as the Bushi. The Twa are the oldest inhabitants of the region. During the 16th century the Lega, agriculturalists of Bantu origin, immigrated into the Bushi region. About one century later the Luzi, who were Ugandese pastoralists of Hamitic origin, infiltrated into the country, reorganized the existing social structures, and built up a feudal system (30, 31). Actually the descendants of the Lega represent at least 90% of the Shi population.

In former times, white cheese was the only dairy product consumed by the Shi (32).

MATERIALS AND METHODS

Participants

Seventy-four healthy volunteers, studying at the Université Nationale du Rwanda (Butare) and originating from the whole territory of Rwanda, were studied. Their average age was 25 years (20–41) and their mean body weight 63.5 kg. Six of them were females. Subjects with diabetes and

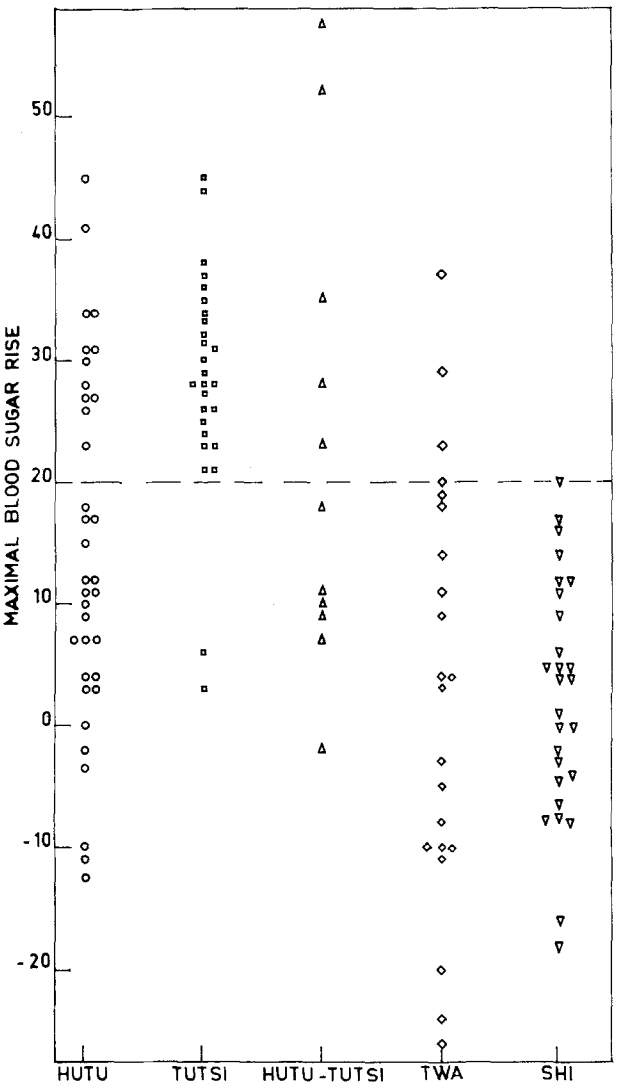

Fig 1. Lactose tolerance tests: correlation of the maximal blood sugar rise with the ethnic origin.

those who underwent a surgical intervention in the gastrointestinal tract were excluded. This group was composed of 36 subjects with Hutu parents, 27 with Tutsi parents, and 11 subjects born from mixed marriages of Hutu and Tutsi.

Another Rwandese group was composed of 22 healthy forest-dwelling Twa from the neighborhood of Butare. Their average age was 24 years (15–58) and their mean body weight 46.8 kg, which is quite normal for this pygmoid race. Eight of them were females. Twelve subjects of this group belonged to 3 families; the remaining 10 were not related to each other.

The third group investigated consisted of 28 Shi students of the Université Nationale du Zaire (Kinshasa). Their mean age was 22 years (19–26) and their mean body weight 60 kg. They were all males.

Lactose Loading Test

The method adopted to evaluate the tolerance of a subject toward lactose has been discussed at length in an earlier work (27). After an overnight fast, the participants received a 20% aqueous solution of lactose in a total amount of 1 g

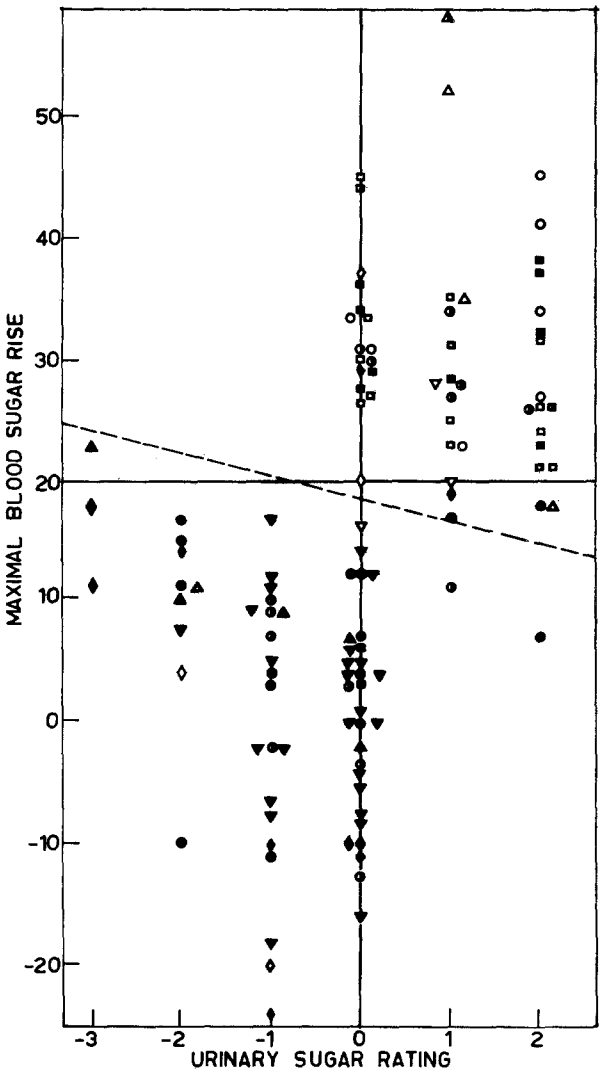

Fig 2. Correlation of the maximal blood sugar rise with the urinary sugar excretion after a lactose loading test. Ratings of galactose excretion are indicated as positive, those of lactose excretion as negative, o, Hutu; □, Tutsi; Δ, Hutu-Tutsi; ◇, Twa; ▽, Shi. Open symbols; no clinical symptoms; blackened symbols; clinical symptoms; half-blackened symbols, data concerning symptoms are not available. The dashed straight line segregates lactose-tolerant subjects from intolerant ones.

lactose per kg body weight. After that, 100 ml water was administered. Fingertip blood samples were taken with a 0.2 ml micropipette just before and at 20, 40, and 60 minutes after the ingestion of lactose. The reducing blood sugars were determined according to the method of Somogyi (33).

During the test, subjects were asked about their milk-drinking habits. The next day clinical symptoms such as diarrhea, borborygmi, abdominal pains, and distension were recorded. Only 73 out of 124 subjects, however, could be contacted after the test.

Urinary Sugars

The subjects emptied the bladders before the test and 1 hour after the ingestion of lactose. In the latter sample the urinary sugars were identified by thin-layer chromatography according to the method of Lewis and Smith (34). The stationary phase consisted of Kieselguhr-G impregnated with phosphate buffer, pH 5; the mobile phase was n-butanol-acetone-phosphate buffer, pH 5 (40:50:10, by volume). After a twofold development, the sugars were stained with aniline phthalate and yielded yellow-green fluorescent spots under ultraviolet light.

Table 1. Prevalence of Primary Adult Lactose Intolerance in Rwanda and Bushi

Tribe	Number	Maximal blood sugar rise (mg/100 ml)		Predominant urinary sugar			Clinical symptoms		
		Mean	Median	Lactose	Galactose	None	(+)	(–)	Not controlled
Hutu-Hutu									
Tolerant	15	+29.7	+31.0	0	11	4	0	6	9
Intolerant	21	+4.0	+5.8	11	2	8	7	2	12
Tutsi-Tutsi									
Tolerant	25	+30.1	+28.0	0	15	10	2	13	10
Intolerant	2	(+6 and +3.5)		0	0	2	2	0	0
Hutu-Tutsi									
Tolerant	5	+38.2	+35.0	0	5	0	0	3	2
Intolerant	6	+9.5	+10.0	4	0	2	2	2	2
Twa-Twa*									
Tolerant	5	+25.6	+26.0	0	1	3	0	2	3
Intolerant	17	- 5.7	- 6.3	7	0	3	3	1	14
Shi									
Tolerant	1	(+20)		0	1	0	0	1	0
Intolerant	27	+1.7	+2.5	10	0	17	26	1	0

*Analysis of urinary sugars was performed on 14 subjects only.

In order to allow a semiquantitative evaluation of the urinary sugars, we distinguished for each sugar 4 ratings according to the intensity of the spots: 0 stands for absence of galactose and lactose, +1 and –1, +2 and –2, +3 and –3 stand for traces (less than 0.2%), moderate (about 1%) and high concentrations (2% and more) of galactose and lactose, respectively. If both sugars were present in a urine sample, the algebraic summation of the galactose and lactose ratings classified the subject (Figure 2).

RESULTS

In the following description each of the populations investigated has been subdivided into a lactose-tolerant and lactose-intolerant group. The classification was based principally upon the maximal capillary blood sugar rise: a rise of 20 mg/100 ml or more indicates tolerance to lactose, a smaller rise indicates intolerance (35). In a few cases, however, where the maximal blood sugar rise was close to 20 mg/100 ml (from 15 to 25 mg/100 ml) but the urinary sugars and clinical symptoms were simultaneously in contradiction with the blood sugar rise, we retained the latter as decisive criteria (27, 36). These cases are discussed individually below and have been compared with Figure 2 to formulate our diagnoses.

Hutu Population

As can be inferred from Figure 1 and Table 1, the participants born from both Hutu parents belong partly to the tolerant and partly to the intolerant group. Of the 15 tolerant Hutu, 2 have a blood sugar rise of +18 and +17 mg/100 ml, respectively, but showed a predominant excretion of galactose. The characteristic features of both subjects class them in the lactose-tolerant group, as shown in Figure 2. None of 7 persons who could be interviewed after the test suffered from the clinical symptoms of lactose intolerance. Eleven subjects showed a predominant galactose excretion and the remaining 4 had no urinary sugars at all.

The more important group of intolerant Hutu was composed of 21 subjects with an average maximal blood sugar rise of +4.0 mg/100 ml. Seven out of 9 persons who could be contacted after the test had suffered from the characteristic clinical symptoms. Eleven sub-

jects showed predominantly lactose in the urinary excretion. Two subjects with blood sugar rises of +7 and +11 mg/100 ml, respectively, had predominant galactose excretion. Judging from their positions in Figure 2, we consider them as lactose intolerant.

Table 1 summarizes the experimental data and indicates for the Hutu population investigated a prevalence of lactose intolerance of 58%.

Of the Hutu participants, 8% drink at least one glass of milk a day, while 23% drank at least one glass of milk daily in their youths. No correlation was found between the milk-drinking habit and lactose tolerance.

Tutsi Population

Of the 27 students born from both Tutsi parents, 25 had a blood sugar rise of 20 mg/100 ml or more, with an average rise of 30.1 mg/100 ml (Figure 1). In 13 cases galactose was the principal urinary sugar. Two out of 15 interviewed subjects, whose blood sugar rise was +25 and +23 mg/100 ml respectively, suffered from diarrhea or abdominal distension, but showed predominance of galactose in the urine. Referring to their positions in Figure 2, we classified them as lactose tolerant.

Out of the 27 Tutsi, 2 had a blood sugar rise of +6 and +3.5 mg/100 ml respectively. Both of them suffered from diarrhea.

From our present observations, one can conclude that the prevalence of lactose intolerance among the Tutsi is near 7%. It appeared that only 20% of the Tutsi subjects drink at least one glass of milk a day.

Hutu-Tutsi Population

Ten students born from Hutu fathers and Tutsi mothers and one born from a Tutsi father and a Hutu mother have been investigated (Figure 1 and Table 1).

Of the 5 subjects, who are to be considered as lactose tolerant, 4 had a blood sugar rise of more than 25 mg/100 ml with predominant galactose excretion. Three of them, who could be interviewed after the test, did not suffer from clinical symptoms of lactose intolerance. One subject with a blood sugar rise of +18 mg/100 ml showed galactose as the principal urinary sugar and did not suffer from clinical symptoms. From his position in Figure 2, we consider this subject as tolerant.

The 6 other subjects had an average blood sugar rise of 9.8 mg/100 ml. Four of them showed predominant lactose excretion and the others no urinary sugars at all. Two out of 4 interviewed subjects reported to have suffered from diarrhea. This group includes the only case of a relative high blood sugar rise of +23 mg/100 ml followed by an exclusive lactose excretion (Figure 2).

The frequency of lactose intolerance in this group of mixed-bred subjects is 55%.

Twa Population

Of 22 subjects born from both Twa parents, 5 are lactose tolerant according to our criteria. Only 2 of them had a blood sugar rise of more than 25 mg/100 ml; they mentioned no specific symptoms and their urine analyses revealed no sugars. Two subjects with a blood sugar rise of +19 and +20 mg/100 ml respectively were classified as tolerant on account of the additional criteria of predominant galactose excretion and the absence of clinical symptoms (Figure 2). For the fifth subject, who had a blood sugar rise of +23 mg/100 ml, additional criteria could not be obtained.

For the other 17 Twa, the mean blood sugar rise was -5.7 mg/100 ml. Three out of 4 interviewed subjects suffered from diarrhea and abdominal pains after the test load. The urinary sugar analysis was only performed on 10 subjects; 7 subjects, including one with a blood sugar rise of +18 mg/100 ml, excreted lactose as the principal urinary sugar and for 3 no sugar at all was detected.

These results (Table 1) indicate that 77% of the Twa investigated are lactose intolerant.

Of the Twa subjects, 35% drink at least one

Table 2. Prevalence of Lactose Intolerance in Three Twa Families

	Maximal blood sugar rise (mg/100 ml)	Clinical symptoms	Ratings of urinary sugars	
			Lactose	Galactose
Family I				
Father P	+3	Not controlled	Not performed	
Offspring of P and M_1	−20	None	−1	0
Offspring of P and M_2	+20	None	0	0
	+4	Not controlled	−2	0
	−10	Not controlled	0	0
mean:	−0.6			
Family II				
Offspring of the	−3	Not controlled	Not performed	
same parents	+14	Not controlled	Not performed	
	−10	Diarrhea	0	0
mean:	+0.3			
Family III				
Offspring of P_1 and M	+37	None	0	0
	+23	Not controlled	Not performed	
Offspring of P_2 and M	+29	Not controlled	0	0
	+9	Not controlled	Not performed	
mean:	+26.5			

glass of milk a day, and 85% remember having consumed about one glass of milk a day in their youths.

Twelve Twa of this group belonged to three different families (Table 2). The first and second family showed a high prevalence of lactose intolerance: 4 out of 5 relatives in family I and all three relatives in family II were intolerant. In family III on the other hand only 1 out of 4 relatives were lactose intolerant.

Shi Population

Of the 28 male students belonging to the Shi population, one subject showed a blood sugar rise of +20 mg/100 ml (repeated) with predominant galactose excretion and no specific symptoms after the test.

The remaining 27 subjects had a mean maximal blood sugar rise of +1.6 mg/100 ml. Twenty-six of them reported clinical symptoms of lactose intolerance and 10 showed lactose as the principal urinary sugar. One subject with a blood sugar rise of +16 mg/100 ml did not experience clinical symptoms of lactose intolerance. Urinary sugar analysis revealed no predominance of either lactose or galactose, so that the case remains doubtful.

From these data we may conclude that 96% of the subjects in the investigated Shi population are lactose intolerant.

Of the Shi who were investigated, 70% drink actually more than two glasses of milk a day, but not necessarily during the same meal.

DISCUSSION

Diagnosis of Lactose Intolerance

The lactose tolerance test has been shown to be a reliable method for diagnosing deficiency of lactase, or "enzyme I of Gray" (37). Generally a capillary blood sugar rise of 20 mg/100 ml or more within one hour after the ingestion of a lactose load can be considered as an indication of the ability to digest lactose (38). Even if this

correlation is usually above 90% (2), additional criteria may still be desirable.

Elliott et al (27) reported a good correlation between urinary sugar excretion and lactose intolerance: tolerant subjects show mostly galactose, intolerant ones lactose as the principal urinary sugar. In the present investigation we were able to confirm this correlation (Figure 2). Of 50 lactose tolerant subjects, 66% showed galactose and none of them showed lactose as the predominant urinary sugar. Of 66 intolerant subjects, on the other hand, 48% showed lactose and 3% galactose as the predominant urinary sugar. Of 56 subjects with a blood sugar rise below 15 mg/100 ml we observed 45% who had lactose and 4% galactose as the principal urinary sugar. It should be noted, however, that the determination of urinary sugars alone is inadequate to diagnose lactose intolerance, since 42% of the subjects shows no predominance of either sugar, and in two cases urinary sugar analysis even leads to erroneous conclusions.

The occurence of gastrointestinal symptoms ensuing a loading test usually confirms lactose intolerance. This subjective criterion alone, however, does not suffice to diagnose beyond doubt a case of individual lactose intolerance (2, 5, 7). In the present survey, 2 out of 28 interviewed subjects with a blood sugar rise of 20 mg/100 ml or more, and 40 out of 46 interviewed subjects with a blood sugar rise below 20 mg/100 ml suffered from the characteristic symptoms of lactose intolerance.

Although neither the analysis of the urinary sugars nor the occurrence of abdominal symptoms can by themselves, if taken alone, be considered as doubtless criteria of intolerance towards lactose, we estimate that the simultaneous occurrence of a negative value for the rating of urinary sugars and the presence of abdominal symptoms allows a diagnosis of intolerance, and conversely the simultaneous absence of symptoms and a positive rating of the urinary sugar code value permit the conclusion that the subject is tolerant. This way to take the additional criteria into account can be useful to formulate diagnoses in the cases where the blood sugar rise remains in the borderline region (15 to 25 mg/100 ml). Although the number of cases at hand is too small to calculate the correlation factor, the risk of error in making a diagnosis in this way does not seem much higher than the one encountered in determining the value of the blood sugar rise.

Another way to formulate a diagnosis is based on the combined use of the blood sugar rise and the result of the analysis of the urinary sugars as expressed in Figure 2. The value of the diagnosis depends in this case upon the correct location and slope of the dividing line which separates the zones of tolerance and intolerance. The location of this dividing line is not so much based on the correct diagnosis of the borderline cases as upon the fact that the points are distributed in two clusters, separated by a rather void intermediate zone, through which a dividing line can be traced with fair confidence.

Lactose Intolerance in Rwanda and in Bushi

Table 1 shows distinctly different frequencies of lactose intolerance in the three major ethnic groups of Rwanda: 77% of the Twa, 58% of the Hutu, and 7% of the Tutsi. Among the Shi, lactose intolerance is even more common; our survey indicates a frequency of 96%. For the Rwandese populations it was not possible to establish a correlation between the prevalence of lactose intolerance and the clanic subdivision.

An interview of the participants revealed no significant differences concerning the milk-drinking habits of the students of Hutu and Tutsi origin: about 85% of them consume less than one glass of milk a day. Practically all students investigated take some milk in tea and coffee. Of the Twa, 35% drink at least one glass of milk a day and 85% remember having consumed about one glass of milk a day in their youths. Of the Shi investigated, 70% drink ac-

tually more than two glasses of milk a day. This confirms that lactose-intolerant adults do not experience any discomfort from milk consumption as long as the amount of lactose consumed does not exceed 10–15 g per meal (9, 16).

At the same time, these findings support the idea that lactose intolerance is of genetic origin rather than the consequence of an individual adaptation to milk consumption (39, 40). The Tutsi and Hima have a very long tradition of cattle raising and cow milking, beginning perhaps as early as 4,000 BC (41). They were great milk drinkers, to the point that milk, mostly fresh, often constituted their principal food supply. On the other hand, it is generally accepted that the Hutu and Twa learned the practice of milking from the Tutsi within the context of the mixed clans, i.e., in the 17th century. The occurrence of a relatively high percentage of lactose-tolerant persons in the Twa (23%), and especially in the Hutu population (42%), may be explained by intermarriage, which is very probable in that they lived in mixed clans. The very high frequency of lactose intolerance in the Shi population is explained by the fact that the descendants of the Hamitic race represent a much smaller fraction of the total population in the Bushi region than in the Rwanda and consequently became more mixed with the Lega of Bantu origin (31).

Another indication of the genetic origin of lactose intolerance results from the family study in the Twa population (Table 2). In two different families, 7 out of 8 relatives are intolerant, whereas in the third family 3 out of 4 members are tolerant toward lactose. It should be pointed out, however, that a more extensive study of all the relatives is required to permit definitive conclusions.

Ferguson and Maxwell (42) admit that lactose intolerance is induced by a factor that suppresses the activity of the brush-border lactase and which is transmitted in an autosomal recessive way. This view is supported by most of the family studies actually performed (2, 43, 44, 45) and by a report of lactose intolerance in 9 descendants of mixed marriage between Asians and Europeans (46).

Assuming that the Hutu and Tutsi populations are genetically in equilibrium and applying the rules of formal genetics, the expected theoretical frequency of lactose intolerance in Hutu-Tutsi is 21% if the lactase-preventing allele is recessive, and 38% if the lactase-suppressing allele is dominant. The observed frequency of lactose intolerance among Hutu-Tutsi being 55%, if it were not for the limited number of data obtained (6 out of 11), one may surmise that intolerance is transmitted as a dominant genetic factor.

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