England

Comparative Analyses of Milks and Substitute Foods

LIBRARY.
SURGEON GENERAL'S OFFICE
JUN 25 1910
851

BY
JOSEPH W. ENGLAND

Director of the
Research Laboratory of Smith, Kline & French Co.
Philadelphia

Copyright 1908, by Smith, Kline & French Co., Philadelphia

Comparative Analyses of Milks and Substitute Foods

COMPARATIVE COMPOSITION OF HUMAN MILK AND COWS' MILK

(At Intermediate Period of Lactation)

	Human Milk			Cows' Milk	
Glycerides of the non-volatile fatty acids	Olein	2.00		1.40	
	Palmitin, Stearin, Dioxystearin, Laurin, Myristin	2.00	4.00 (Fat)	2.25	4.00 (Fat)
Glycerides of the volatile fatty acids	Butyrin, Caproin, Caprylin, Caprin	trace		0.35	
Proteids	Casein	0.75		3.00	
	Albumin	1.00		0.50	
	Opalisin	trace	1.75		3.50
	Globulin	trace		trace	
	Galactin			trace	
	Fibrin			trace	
Milk Sugar			6.50		4.50
Citric Acid (as Citrates)		(0.05)	trace	(0.125)	trace
Salts			0.25		0.75
Total Solids			12.50		12.75
Water			87.50		87.25
			100.00		100.00

American pediatrists generally accept the following standard of percentages for human milk: Fat, 3 to 5 per cent.; proteids, 1 to 2 per cent.; and sugar, 6 to 7 per cent., the average being fat, 4 per cent.; proteids, 1.5 per cent., and sugar, 7 per cent.; but generally, at the intermediate period of lactation, at least, the fat is nearer 4 per cent. than 3, the proteids nearer 2 per cent. than 1, and the sugar between 6 per cent. and 7, or ratio of 4, 1.75 and 6.50.

As to the standard of percentages for cow's milk, American pediatrists generally accept the following: Fat, 4 per cent.; proteids, 3.5 per cent., and sugar, 4.5 per cent., though for the purpose of ready calculation it is often assumed that cow's milk contains fat, 4 per cent.; proteids, 4 per cent., and sugar, 4 per cent.

A comparison of the foregoing figures with those of the following tables will show the dfferences in composition between human milk, cow's milk and a number of substiute-foods prepared for a six months old child.

PERCENTAGE COMPOSITION OF INFANT FOODS AS PREPARED FOR USE

(Sixth Month Formulas)

	Fat	Proteids	Milk Sugar	Salts	Starch	Dextrin, Maltose, etc.	Cane Sugar
Eskay's Food (Regulation Formula at 6th month; from Rich Cow's Milk)*	3.00	2.50	Milk Sugar and Starch 6.00	0.50	1.25		
(Top Milk Formula at 6th month)*	4.00	1.75	" 6.00	0.50	1.25		
Mellin's Food (Chittenden)	2.89	2.62	3.25	0.47		2.73	
Horlick's Malted Milk, (Chittenden)	0.68	1.15	1.18	0.29		4.20	
Nestle's Food; Old Formula, (Chittenden)	0.36	0.81	0.84	0.13	1.99	0.44	2.57
Nestle's Food; (New Formula)*	0.92	2.39	1.09	0.34	2.56	4.56	4.16
Allenbury's Food, No. 3*	1.59	2.67	2.40	0.40	5.40	1.90	0.10
Wampole's Milk-Food, Malted, (Fischer)	0.73	1.58	0.99	0.46		7.65	
Wyeth's Prepared Food*	0.64	3.26		0.75	2.46	Sol. Carb. incl. Lactose 12.00	
Cereal Milk, (Fischer)	0.38	1.09		0.21		Sol. Carb. incl. Lactose 7.34	
Just's Food*	2.50	2.22		0.49		Sol. Carb. incl. Lactose 6.80	
Imperial Granum (Chittenden)	1.54	2.15	2.71	0.34	1.22	0.58	
Sunbright Food, (LaWall)	2.03	2.00	2.25	0.39	2.42	Sol. Carb. 0.24	
Barley Water, (Holt)	0.05	0.09		0.03	1.63		
Barley Water, (Blyth)	0.02	0.03		0.03	0.39	Sugar 0.05	
Eskay's Food and Water only (4%) (for diarrhea)*	0.125	0.25	2.00	0.05	1.25		
Whey from whole milk, (Adriance)	0.96	0.94	5.49	0.48			
Whey from skimmed milk, (Adriance)	0.04	1.17	5.36	0.52	Lactic Acid		
Buttermilk, (Vieth)	0.50	3.60	4.06	0.75	0.80		

Peptonized or Humanized Milk	Prepared with milk (8 parts), water (8 parts) and cream (2 parts), and Peptogenic Milk Powder the proteids are "converted chiefly into partial peptones, and in this form they cannot be said to resemble the proteids of human milk, which have not been acted upon by a proteolytic ferment." (Fischer)
Benger's Food	Prepared with milk (½), water (½), and Food, "the proteids are partially digested, and most, but not all, the starch is converted into soluble forms." (Hutchison)

*From data given by manufacturer.

PERCENTAGE COMPOSITION OF CONDENSED MILKS. (As prepared for use.)

		Fat	Proteids	Milk Sugar	Cane Sugar	Salts
Eagle Brand (Smith, by Holt).....	With 6 parts of water	0.99	1.20		Cane and Milk Sugars " 7.23	0.17
"	With 12 parts of water	0 53	0.65		" 3.90	0.10
"	With 18 parts of water	0.36	0.44		" 2.67	0.07
Anglo Swiss, Milk Maid Brand, (by Fischer)...	With 7 parts of water	1.70	1.50	2.26	6.00	0.36
"	With 14 parts of water	0.92	0.82	1.23	3.25	0.19
Eagle Brand, (by Fischer)	With 7 parts of water	1.18	1.31	1.53	6.59	0.29
"	With 14 parts of water	0.64	0.71	0.83	3.57	0.16
Nestle's Swiss Milk, (by Fischer).....	With 7 parts of water	2.14	1.51	2.34	5.81	0.25
"	With 14 parts of water	1.16	0.82	1.27	3.15	0.14

A study of the digestion of milk in the light of modern investigations reveals the following interesting facts:

Human Milk with Gastric Juice.—When human milk comes in contact with gastric juice, the rennet ferment changes its casein (calcium-casein) into calcium-paracasein curd, and then the acid of the gastric juice (if in small amount) decalcifies the calcium-paracasein, and changes it into calcium chloride and free paracasein curd, after which the acid (if in larger amount) changes the latter into paracasein chloride curd. For reasons to be stated later, the paracasein chloride is not formed by healthy gastric juice. The presence of curds in the stomach is of the highest importance physiologically, stimulating, as they do, the development of both the motor and chemical functions of the stomach.

The curds from human milk are soft and flocculent, while those from cow's milk are large and coarse, such as would be adapted for developing the digestive apparatus of the calf for its later work of digesting tough and fibrous food.

The Acidity of Gastric Juice.—The acidity of gastric juice varies with the time of nursing, increasing from none to a maximum, and then decreasing to none. In nurslings the acidity averages about 0.1 to 0.2 per cent., and in adults from about 0.2 to 0.3 per cent. The acid is slowly secreted at first, but "as more acid is secreted it combines with more of the rennet curds, and gives more work for the pepsin secreted. In this way the work of the stomach increases as fast as the secretion of digestive juice increases; mother's milk thus automatically adapts itself to the young animal's digestive apparatus. If mother's milk did not alter to meet the increased quantity of the digestive juices, the infant stomach would find less work as it grew stronger, with consequent atrophy." (Chapin.)

Cow's Milk with Acids.—When cow's milk comes in contact with an acid, as the researches of Van Slyke and Hart (New York Agr. Exp. Station, by Journ. Chem. Society, 1905, 679; also Journ. Soc. Chem. Industry, Oct. 15, 1907, 1061) have clearly shown, two distinct substances are formed in succession. When a **small** amount of an acid is added to milk, the casein (calcium-casein) is decomposed, and free or uncombined casein is precipitated, which is plastic and ductile, and soluble in a warm 5 per cent. solution of sodium chloride; and when this precipitate is treated with an additional amount of acid, a casein compound of the acid is formed, which is destitute of the plastic and ductile properties of the freshly precipitated casein, and is insoluble in a warm 5 per cent. solution of sodium chloride. In other words, using hydrochloric acid as the precipitant, the calcium-casein is first decomposed into calcium chloride and free casein, and the latter, with an excess of acid, is then changed to casein chloride.

Cow's Milk with Gastric Juice.—When, however, the milk is first treated with the rennet ferment, and then with hydrochloric acid (as with gastric juice), the reactions are more complex. The rennet decomposes the calcium-casein to calcium-paracasein, a gelatinous curd (junket clot, or curds and whey), and then the acid, **if in small amount,** changes the calcium-paracasein into calcium chloride and free paracasein (a tough curd), or **if in larger amount,** changes also the free paracasein into

paracasein chloride (a cheesy curd). Rennet will not change the tough curds of free paracasein into the gelatinous curds of calcium-paracasein.

The calcium-paracasein curd yields on incineration from 5 to 8 per cent. of an ash, consisting almost entirely of calcium phosphate; the casein curd formed with acids yields on incineration only traces of ash, showing decalcification. Pepsin will not attack calcium-paracasein; the latter must first be decalcified into free paracasein, after which it is changed by pepsin into absorbable compounds. It may be that other salts than the calcium phosphates are involved in the reactions, since Soldner has shown that the salts of milk contain nearly 33 per cent. of alkali—and alkali-earth citrates, while he found only about 16 per cent. of the calcium phosphates; but, so far, this has not been demonstrated.

Van Slyke and Hart have shown also that "when the amount of lactic acid in cream exceeds 0.5 per cent., the casein in buttermilk is present as casein lactate." As the percentage of hydrochloric acid in the gastric juice of nurslings is usually only 0.1 to 0.2 per cent., and that of adults from 0.2 to 0.3 per cent., it is apparent that in the normal digestion of cow's milk paracasein only is formed.

Perhaps the best illustration of these changes may be had by the following:

With Hydrochloric Acid	With Rennet and Hydrochloric Acid
(1) Calcium-Casein + Hydrochloric Acid (small percentage) = Calcium Chloride + Free Casein (tough curd).	(1) Calcium-Casein + Rennet = Calcium-Paracasein (gelatinous curd).
(2) Free Casein + Hydrochloric Acid (larger percentage) = Casein Chloride (cheesy curd).	(2) Calcium-Paracasein + Hydrochloric Acid (small percentage) = Calcium Chloride + Free Paracasein (tough curd).
	(3) Free Paracasein + Hydrochloric Acid (larger percentage) = Paracasein Chloride (cheesy curd).

The Function of Curds.—As Chapin (Infant Feeding, 1904, 213) points out, "the milk of animals whose digestion takes place principally in the stomach forms solid curds that leave it with difficulty (cow's, goat's and sheep's milk); and the milk of animals whose digestion is principally intestinal, forms soft gelatinous curds which easily pass into the intestines (mare's and asses' milk). The human digestive tract stands between the two types and, consequently, neither cow's or asses' milk fits it."

It is a significant fact also that the milks of those animals whose digestion is principally gastric, contain in their total proteids a much larger proportion of casein to albumin than do the milks of those animals whose digestion is principally intestinal. Thus an examination of Koenig's analyses show that in the mean of the minimum and maximum percentages of cow's milk, the ratio of casein to albumen is about 6 to 1, in goat's milk 3 to 1, and in sheep's milk 3 to 1, while in mare's milk it is 1.5 to 1, and in asses' milk 1 to 2.3. Human milk is intermediate, being nearly 1 to 1.

It is important to note also that the maximum ratio of casein to albumin in cow's milk is about 7 to 1, and the minimum is 4.5 to 1; the maximum of goat's milk is 3 to 1, and the minimum is 2 to 1; and the maximum of sheep's milk is 4 to 1, and the minimum 3 to 1. These figures are simply approximate, the ratios varying to meet individual needs. Chapin, for example, reports the analyses of the milk of 1,500 cows, which "shows that the relation of albumin to casein is a very variable one, instead of being constant, and in no single instance did any sample of the mixed normal milk contain as much as 5 parts of casein for 1 of albumin, the highest being 4.9, while the average was 3.76 parts of casein for one of albumin."

These variations in the ratios of casein to albumin in the milks of animals are not accidents of nature. They are in direct obedience to the law of supply and demand. **They mean simply that the proportion of difficultly-digestible food material (casein) to the readily-digestible food material (albumin) is adjusted by nature to meet the needs of the individual animal for the proper development of the motor and chemical functions of its stomach and intestines.** Naturally with the larger animals more solid food (casein), and less soluble food (albumin), is required to stimulate the development of the functions than with the smaller animals; and hence the larger proportion of casein and the smaller proportion of albumin in their food, while with the smaller animals the reverse holds. So far as the food value of the two proteids are concerned, they are probably of equal value to the body.

The ratio of casein to albumin, therefore, varies not only with different animals, but in the same animals of the same age, in obedience to individual needs; though

the latter variations are within much narrower limits than the former. A sixteen-pound infant, for example, requires more casein than a twelve-pound one, though both may be six months of age. Hence it follows that human milk is a food of constantly changing composition, especially during the period of lactation. At birth much albumin and little casein is needed, and then as the child grows and develops more and more casein is needed, and less and less albumin.

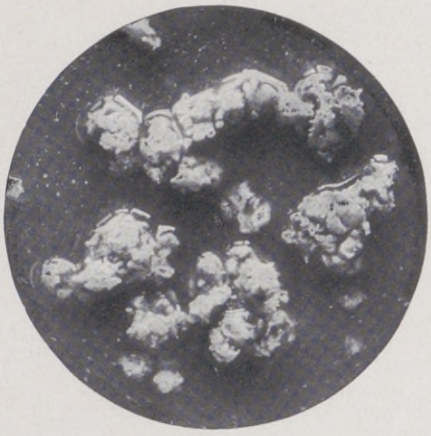
As to the effects of a disturbance of the ratio of casein to albumin in human milk at different periods, the following from Hutchison (Food and Dietetics, 1906, 433) is of interest: "There is some scientific justification for the popular view that a wet nurse should not suckle a child which is younger than her own. Monti claims that a child from one to six weeks old should have a wet nurse whose child is not more than two months. A child from two to four months requires a nurse who has not been suckling for more than three or four months. Whether for older babies a younger nurse is admissible depends on the age of the child. A nurse whose own infant is two to three months old will do for a child six or eight months, but for a three months child the first milk is often insufficient."

The Chemical Modification of Curds.—There is no chemical method of converting the difficultly-soluble paracasein into the easily-digested albumin, so that the ratio of the former to the latter may be changed to correspond with that of human milk. It is true that paracasein may be converted into soluble compounds with proteolytic ferments or predigested, but these do not require the exercise of motor and chemical functions for their absorption, and hence lack one of the chief essentials of a food. The function of a food is not only nutritional; it is, also, developmental. Not only should it furnish food to the cellular tissue, but it should also require work for its digestion in order to stimulate the development of the motor and chemical functions of the digestive tract.

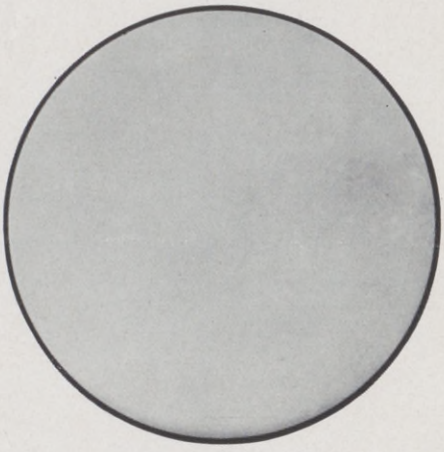
The Mechanical Modification of Curds.—While it is not possible to chemically change paracasein into albumin, it is possible to obtain, practically, the same result by mechanical means. With the use of cereal decoctions, such as Eskay's Food, we can mechanically change the tough paracasein of cow's milk into fine flakes resembling those formed by human milk and gastric juice (see ill. No. 3), and so minimize the indigestibility of paracasein, as to make it approach in its digestibility the digestibility of albumin itself. This result is due to the fact that ferments act only at points of contact, and hence attack the surfaces of fine flakes (with their many surfaces) with the expenditure of much less digestive energy than the surfaces of tough masses (with their few surfaces). This, then, is one of the strongest features of value in Eskay's Food. Not only does it make a milk-food that simulates human milk, chemically, but it mechanically modifies cow's milk so that its digestibility is made to approach the digestibility of human milk.

The Emulsification of Fat.—There is another feature that is scarcely less important. When Eskay's Food is boiled with water (in the preparation for use), all its insoluble starch is gelatinized, and, mixed with cow's milk, and present in the human stomach, it not only mechanically flakes the casein, but also emulsifies or mechanically prevents the oil globules of the milk-fat from coalescing, decomposing and causing fat-indigestion.

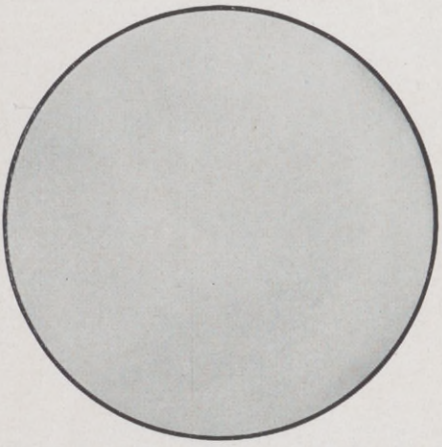
With cow's milk (as probably with human milk), the size of the fat globules varies during the act of nursing, being quite small at the beginning, and progressively increasing in size until, at the end of the act, they are from 1.5 to 7 times the original size. (New York (Geneva) Experiment Station, Collier; quoted by Chapin). In addition, the fat of human milk is much more finely emulsified than that of cow's milk. Since proteid digestion precedes fat digestion, it is obvious that, if the stomach of the infant be given large-sized oil globules, instead of small, coalescence of the fat and chemical decomposition can readily take place; and to prevent this the use of an emulsifying agent like gelatinized starch, as in Eskay's Food, is of the highest value.



1. Unmodified Cow's Milk as it appears in the human stomach



2. Human Milk as it appears in the human stomach



3. Cow's Milk modified with Eskay's Albumenized Food as it appears in the human stomach