THE OSMOTIC PRESSURE OF LIQUID FOODS

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One of the admitted functions of the stomach is the osmotic equilibration that takes place between the blood and the fluid food swallowed. Hypertonic solutions are diluted and hypotonic solutions have salts, etc., added until isotonicity is attained, though it may be a matter of debate whether the diluting (or concentrating) fluid is physiologically secreted or is due to physical diffusion. That the lining cells of the mucous membrane of stomach and gut would be injured by prolonged contact with a hypertonic fluid may be stated *a priori*. Even the mucous membrane of the mouth is open to injury in this way—witness the ‘roughness’ produced when a piece of confectionery is retained for a few minutes between the teeth and cheek. Also the discomfort which follows the intake of such substances as strong salt solutions, very strong soups, or peptone solutions which ‘irritate’ the stomach, is thus easily explainable.

The object of the present research was to determine the osmotic pressure of the fluids ordinarily admitted to the stomach, and at the same time to discover whether the sense of taste afforded us any guidance in the choice of fluids with reference to their osmotic pressure, more particularly as regards the rejection of the hypertonic. Of the food-stuffs ordinarily eaten, the vast majority are in solid or gelatinous or colloidal form. To such substances the consideration of osmotic pressure cannot apply. The actual fluid foods admitted to the stomach are milk, the ordinary beverages, fruit juices, beef-tea, meat extracts and soups. In tea, coffee, or cocoa there is usually a sugar addition which varies with personal taste, whilst in beef-tea, soups, etc., common salt is invariably an added ingredient. The osmotic pressure of milk has been determined so frequently that I have not thought it necessary to make any confirmatory experiments. In the case of soups the ‘salting to taste’ was carried out by a laboratory attendant, who was not aware of the

purpose of the research. The Beckmann freezing point method was employed throughout. A mixture of ice and salt water was used to produce the requisite cold, but care was taken to prevent excessive supercooling. In none of the recorded readings was the degree of supercooling more than about 1.5°C . Crystallisation was started by inoculation with a fragment of frozen distilled water. The stirring was carried out by a simple clock-work mechanism. Centigrade scale employed throughout.

RESULTS.

Beverages

Coffee.—(2 spoonfuls of sugar in ordinary breakfast cupful.) (1) Δ 0.341°C .; (2) Δ 0.343°C .

Tea Infusion.—(2 teaspoonfuls, about 12 c.c., of tea in 200 c.c. boiling water.) Allowed to infuse 5 minutes. (1) Δ 0.052°C .; (2) Δ 0.049°C .; (3) Δ 0.050°C .

Tea.—(100 c.c. Infusion, 50 c.c. water, 25 c.c. milk, 10 grms. of sugar.) Tasted 'just nice.' (1) Δ 0.457°C .; (2) Δ 0.458°C .; (3) Δ 0.456°C .

Tea.—Second infusion, made with 200 c.c. more water added to leaves from infusion and allowed to stand 35 minutes. (1) Δ 0.026°C .; (2) Δ 0.025°C .

Lemon Juice.—(As used in Melbourne Hospital.) Strained juice of lemon (one lemon) 33 c.c. in 250 c.c. distilled water. (1) Δ 0.126°C .; (2) Δ 0.125°C .; (3) Δ 0.122°C .

100 c.c. of diluted juice + 1 teaspoonful (5 grms.) cane sugar added. Tasted 'just right.' (1) Δ 0.487°C .; (2) Δ 0.485°C .

Beer.—(Carlton draught XXX Beer.) (1) Δ 2.407°C .; (2) Δ 2.409°C .

Wine.—(Cheap Australian claret.) Cooled to -5°C ., but ice would not separate out.

Wine.—Kept between 77°C . and 80°C . for 35 minutes, and then boiled briskly for about 7 minutes to get rid of alcohol, at end of which time boiling point rose to about 103°C . 75 c.c. of wine subjected to this treatment yielded 45 c.c. (1) Δ 3.240°C .; (2) Δ 3.238°C .; (3) Δ 3.241°C .

Foodstuffs

Treacle.—Diluted with water to 1 in 7 and this solution gave Δ 1.730°C .

Peptonised Milk.—Benger's peptonised milk as used at the Melbourne Children's Hospital, Carlton, Melbourne, Victoria.

Benger's Milk 'A.'—(Milk 3, water 1, peptonised 20 minutes. Boiled. Sweetened with cane sugar about 1 oz. to 1 pint milk.) One drop gave pink biuret reaction. (1) Δ 0.652°C .; (2) Δ 0.656°C .

Benger's Milk 'B.'—(Milk 2, water 1, peptonised 20 minutes. Sweetened.) (1) Δ 0.630°C .; (2) Δ 0.628°C .; (3) Δ 0.626°C .

Peptonised Milk.—(Milk 4, water 1, peptonised 20 minutes.) (1) Δ 0.548°C .; (2) Δ 0.546°C .

Soups.—An ordinary soup which had been served up but rejected as unpalatable on account of salt taste. Δ 1.984°C .

A Vegetable Soup was made of the following ingredients:—Carrot, 100 grms.; parsnip, 110 grms.; turnip, 55 grms.; spring onion, 47 grms.; celery, 25 grms.; parsley, 12 grms.; water (distilled), 1500 c.c. Brought to boil and kept simmering for $2\frac{1}{2}$ hours. Strained. Salted to different degrees.

Vegetable Soup Plain.—(1) Δ 0.374°C .; (2) Δ 0.373°C .; (3) Δ 0.372°C .

Vegetable Soup Salted.—

- A. Soup + salt to 4 per cent. Δ 2.757° C.
- B. Soup + salt to 2 per cent. Δ 1.536° C.
- C. Soup + salt to $\frac{1}{2}$ per cent. (1) Δ 0.851° C.; (2) Δ 0.856° C.
- D. Soup + salt to $\frac{1}{4}$ per cent. Δ 0.780° C.
- E. Soup + salt to $\frac{1}{8}$ per cent. (1) Δ 0.586° C.; (2) Δ 0.584° C.; (3) Δ 0.582° C.

The verdict of the taster was :—The unsalted vegetable soup possessed a very flat and unsatisfactory taste. A, B, C, and D distinctly too salty. A and B distinctly unpleasant taste. E was about right.

Beef Tea.—Made with about 6 c.c. meat extract (Fitzroy Brand, Queensland manufacture) in 1000 c.c. distilled water.

Beef Tea Plain.—(1) Δ 0.141° C.; (2) Δ 0.139° C.; (3) Δ 0.140° C.

Beef Tea Salted.—

- A. Beef tea + salt to 2.5 per cent. (1) Δ 1.626° C.; (2) Δ 1.626° C.; (3) Δ 1.625° C.
- B. Beef tea + salt to 1.25 per cent. (1) Δ 0.882° C.; (2) Δ 0.887° C.; (3) Δ 0.886° C.
- C. Beef tea + salt to 0.625 per cent. (1) Δ 0.546° C.; (2) Δ 0.544° C.; (3) Δ 0.543° C.
- D. Beef tea + salt to 0.416 per cent. (1) Δ 0.419° C.; (2) Δ 0.416° C.

Sample C was much the tastiest—just salted to taste. A and B having too much salt, and sample D and the original not enough salt.

Beef Tea made with about 6 c.c. meat extract in 1000 c.c. boiling distilled water. Δ 0.160° C.

Beef Tea Salted.—Salt added till the flat and unsatisfying taste of the beef tea was abolished, but still no salty taste perceptible.

Taster A. (1) Δ 0.330° C.; (2) Δ 0.331° C.

Taster B. (1) Δ 0.329° C.; (2) Δ 0.330° C.

Beef Tea Over-salted.— Δ 1.922° C.

Sugar Solutions

Dextrose Solutions.—100 c.c. taken into mouth in sips of 25 c.c., each sip kept in mouth $\frac{1}{2}$ minute, spat out; in $\frac{1}{2}$ minute another sip taken, kept in $\frac{1}{2}$ minute, spat out; and so on for four sips.

10 per cent. Dextrose Solution. Δ 1.156° C.

10 per cent. Dextrose Solution Salivated. (1) Δ 1.068° C.; (2) Δ 1.066° C.

5 per cent. Dextrose Solution. Δ 0.566° C.

5 per cent. Dextrose Solution Salivated. (1) Δ 0.536° C.; (2) Δ 0.532° C.; (3) Δ 0.534° C.

Cane Sugar Solution, 20 grms. in 150 c.c. (13.3 per cent). 100 c.c. treated in similar manner as dextrose solution above, 7 c.c. Saliva were added by this process to the 100 c.c. sugar solution, and there was an after secretion for several minutes.

Cane Sugar Solution (13.3 per cent.) Δ 0.868° C.

Cane Sugar Solution Salivated. (1) Δ 0.788° C.; (2) Δ 0.792° C.

Fruit Juices

Lemon.—Weight 140 grms. Peel and connective structure 90 grms. Yielded 40 c.c. strained juice. (1) Δ 0.937° C.; (2) Δ 0.940° C.; (3) Δ 0.939° C.

Orange.—Orange 135 grms. Yielded 50 c.c. strained juice. (1) Δ 1.100° C.; (2) Δ 1.101° C.; (3) Δ 1.100° C.

Pineapple Juice.—From fresh Queensland pineapple. (1) Δ 1.462° C.; (2) Δ 1.464° C.; (3) Δ 1.460° C.

Cocoanut 'Milk.'—(About 150 c.c. were yielded by the nut.) (1) Δ 0.521° C.; (2) Δ 0.518° C.; (3) Δ 0.518° C.

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Saline Aperients

Magnesium Sulphate Solution.—(15 grms. in 100 c.c.) Δ 1.136° C.

Balanced Saline Aperient.—(The stronger one) as recommended by Professor W. A. Osborne in a paper in the *Intercolonial Medical Journal* of Australasia, July 20th, 1909.

(1) Δ 0.864° C.; (2) Δ 0.862° C.; (3) Δ 0.861° C.

Saliva produced from Sucking Confectionery.—Barley-sugar stick (about 12 grms.) sucked for 15 minutes led to production of 72 c.c. Saliva. (1) Δ 1.008° C.; (2) Δ 1.006° C.

Saliva from about 30 grms. boiled cane sugar. Sweetmeat — 100 c.c. (1) Δ 1.488° C.; (2) Δ 1.484° C.

GENERAL CONCLUSIONS

It will be seen from the above experiments that of all the fluid foods which are admitted to the stomach, alcoholic beverages and fruit juices alone are hypertonic. Further, it may be safely stated that in no case is a fluid admitted in which hypertonicity is due to the mineral ingredients alone. When, therefore, we find the kidney elaborating a fluid (urine) with sufficient saline ingredients to render it hypertonic, we must regard the high concentration of this fluid as so much external work done and of sufficient moment to be taken into consideration in calorimetric experiments on an animal or on the human subject. These experiments also demonstrate that we must ascribe to the sense of taste a distinct *osmotactic* character. Not only is this sense potent in testing the food qualitatively, but also from the quantitative standpoint of molecular concentration. Even those hypertonic fruit juices which are admitted to the stomach are passed, so to say, under protest, for their taste is recognised as astringent or highly acid, and are apt to be followed by a sense of thirst.

The mechanism is faulty, however, when dealing with alcoholic beverages, a fact which we may ascribe to the artificiality of fermented liquors, and their manufacture and consumption being restricted to man only. The great majority of fluid foods are, however, hypotonic, and thus a margin is left for the addition of hydrochloric acid and other constituents of the gastric juice. With regard to alcoholic beverages, it may be stated that a solution of alcohol in pure water, isotonic with the blood, would only be about 1.5 per cent. As this percentage is almost invariably exceeded in fermented (and, of course, distilled) liquors, and as other substances are present in addition, the high osmotic pressure of the beer and wine tested is not surprising.

The association of the raising of osmotic pressure of beverages with

the induction of thirst is made use of in some departments of commerce by the excessive salting of wines and the over-sugaring of 'summer drinks.' In the case of cane sugar, a solution isosmotic with the blood would be about 11 per cent., whereas the fluid which reaches the stomach as a result of even the slow methods of ingestion of sweetmeats, as exemplified in the process of sucking confectionery, is much higher than this, and accounts for the disagreeable after-results very often experienced after over-indulgence in such delicacies.

In conclusion, I desire to express my sincere thanks to Professor W. A. Osborne for his kind advice and suggestions afforded and interest taken in this work.