Sodium-Potassium Chloride Mixtures as Table Salt

Robert L. Frank
Morton International, Inc.
Woodstock, Illinois
Olaf Mickelsen
Michigan State University,
East Lansing, Michigan

ABSTRACT

Mixtures of sodium and potassium chlorides :ve been found much more palatable than one ɔuld anticipate from the tastes of the individual .lorides. Sodium chloride masks the disagreeable ıvor of potassium chloride, and in addition mixres are nearly as salty as equal weights of sodium .loride. They are therefore proposed as potential placements for ordinary salt in the diets of hy'rtensive patients and others requiring sodiumstricted diets. Even though they still contain dium, they may prove useful since (a) present lt substitutes are unsatisfactory from the taste ındpoint, and (b) the introduction of thiazide ·ugs has eliminated the necessity of drastic soum restriction for most hypertensive patients.

The similar physical properties of sodium and ›tassium chlorides also render their mixtures atıctive as salt replacements; mixtures are visually distinguishable from ordinary salt. Applications ay exist for industrial food processing as well as r salting of food in the home.

The extra intake of potassium resulting from the e of these mixtures should pose no physiological ·oblems. The amount thus added to the diet does ›t bring the total intake beyond normal limits. ›tassium chloride, when taken orally, is almost ›n-toxic.

Salt is essential in human nutrition. The use of ›dium chloride is so common that Americans con.me an average of 10 grams daily and inhabitants ' certain areas of Japan as much as 27 grams (Dahl, 1958a, b, c, 1960, 1961b; Meneely, 1961a). Although the actual level needed by the human body has not been reliably established, Dahl (1958b, c) has shown that daily ingestion of only 250-375 milligrams of sodium chloride (100-150 mg. sodium) by adults can be maintained without any apparent signs of abnormalities. Salt intake is not a concern of most people; however certain disease conditions for years have been treated by salt restriction.

The most common of such diseases is hypertension or high blood pressure (Dahl, 1954, 1963; Food and Nutrition Board, 1954; Pike, 1964; Ambard, 1904; Allen, 1922; Kemper, 1944, 1948; Grollman, 1945; and Addison, 1928). Dahl (1958 b, c, 1961a) has stated that one-fourth to one-third of hypertensive patients respond with a reduction in blood pressure when put on a salt-restricted diet. Various other diseases also respond to salt restriction: edematous heart disease (Achard, 1901), congestive heart failure (Wheeler, 1947; Iseri, 1950; Food and Nutrition Board, 1954; Pike, 1964), renal diseases, cirrhosis of the liver, toxemias of pregnancy and Meniere's disease (Food and Nutrition Board, 1954; Pike, 1964).

The major difficulty encountered with salt restriction is one of taste. Unsalted food is unpalatable to most persons. For this reason various "salt substitutes" have been developed. Those most commonly used are based on potassium chloride, which has an unpleasant, rather bitter taste. Combinations of potassium chloride with citric or other acids, monopotassium glutamate, choline, ammonium chloride or spices are often used, but these do not have the agreeable, salty flavor of sodium chloride (Food and Nutrition Board, 1954; Pike, 1964). Lithium chloride, both palatable and salty is toxic to humans and cannot be used (Schou, 1957).

In an effort to reduce sodium intake in hypertensive patients without depriving them of a palatable salty seasoning, we have studied mixtures of sodium and potassium chlorides.

Sodium-potassium chloride mixtures.

Our experiments with different mixtures of sodium and potassium chlorides have shown that in mixture the disagreeable flavor of the potassium is masked. A panel of 72 students from Michigan State University tasted solutions of potassium chloride alone and various mixtures of sodium and potassium chloride solutions. The results (Fig. 1)

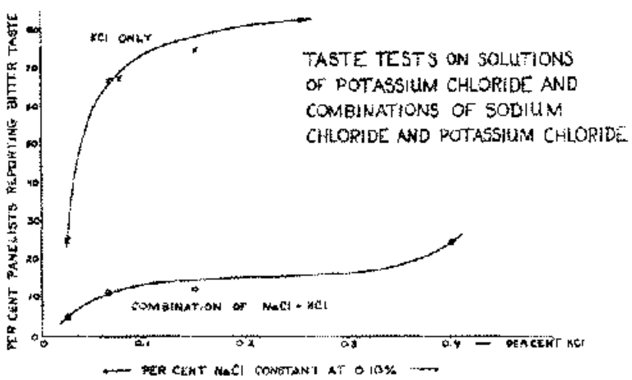

Figure 1.

show that a 0.064% solution of potassium chloride was bitter to 67% of the panelists. A 0.4% solution of potassium chloride alone was so bitter to all panelists that it could not be accurately evaluated—the complaint was that the bitter flavor lingered and interfered with subsequent tasting. However, this same concentration of potassium chloride in mixture with 0.1% sodium chloride tasted bitter to only 24% of the panelists.

Further tasting experiments revealed that potassium chloride at concentrations above the taste threshold of 0.025-0.050% contributes its own saltiness to almost the same extent as that of ordinary salt (Fig. 2). Weight-for-weight, then, mixtures are almost as salty as sodium chloride.

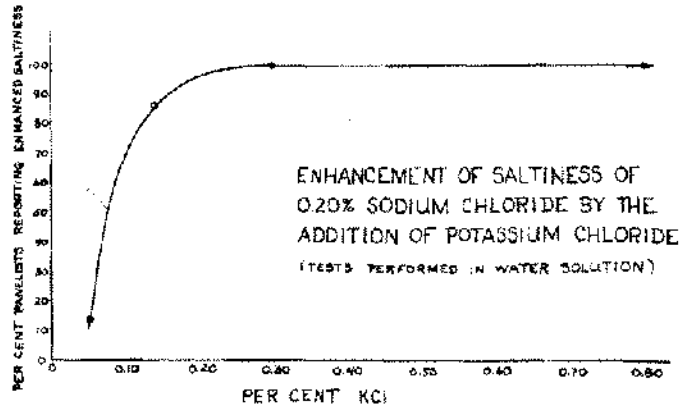

Figure 2.

Additional tests were carried out to evaluate the mixtures of sodium and potassium chlorides under actual cooking and eating conditions. Twelve graduate students majoring in foods and nutrition were provided a noon meal for ten days. Each day all panelists received the same meal. The same menu was followed for five days. A different "salt" was used on each day of each five-day period, both for cooking and at the table. This salt ranged from pure sodium chloride to mixtures of sodium chloride with increasing concentrations of potassium chloride. Each panelist had an individual shaker, and the weight of "salt" used from each shaker was determined after each meal. The average amount of the various "salts" used by each panelist was: 100% NaCl, 2.30 g.; 80% NaCl: 20% KCl, 2.25 g.; 70% NaCl: 30% KCl, 2.25 g.; 60% NaCl: 40% KCl, 2.25 g.; 40% NaCl: 60% KCl, 3.05 g. Individual values, unlike these averages, showed a great deal of variation, indicating that the panelists salted their food by taste rather than habit. Mixtures containing up to about one-half potassium chloride thus appear to be as salty as sodium chloride. None of the panelists in this study indicated unpleasant or unusual reactions to foods prepared and seasoned at the table with mixtures of sodium and potassium chlorides. In fact, none of the twelve panelists guessed it was the table salt that was being varied.

The taste experiments have shown that mixtures of sodium and potassium chlorides can be considered both palatable and salty and, as such, are feasible in reducing sodium intake in salt-restricted patients. These mixtures cannot be called "salt substitutes" because sodium is still present. However, since the introduction of thiazide drugs for the treatment of hypertension, the hypertensive patient no longer needs such drastic salt restriction. Consider for example use of a 1:1 mixture by weight. This ratio may have some advantages since it provides only half as much sodium as does ordinary salt, yet its palatability is favorable to a large percentage of the population. A salt-restricted patient using it at the table instead of salt can achieve twice as much "saltiness" without affecting his total sodium intake. Such a mixture contains 19.65% sodium and 26.20% potassium.

The physical properties of potassium chloride make it technically an ideal substance for mixing with ordinary salt. Both salts are colorless, transparent cubic crystals with similar refractive indices obtainable in any desired particle size. Thus, visually a mixture of the two is indistinguishable from pure sodium chloride. The specific gravity of sodium chloride (2.16) is similar to that of potassium chloride (1.99) so that mixtures will not segregate. Critical humidities for sodium and potassium chlorides (76% and 86% and 25°C) are such that mixtures can be protected from caking by the same freeflowing additives as are used with sodium chloride. Mixtures can be readily iodized.

These similar properties make possible the use of sodium-potassium chloride mixtures in food processing as a replacement for ordinary salt for dietetic purposes. Testing has shown this to be possible even where salt has a functional use in addition to its taste effect, as in baking bread and curing meat. Loaves of bread made with sodium chloride, potassium chloride or a 1:1 mixture of these two salts were very similar in dough fermentation, carbon dioxide retention, loaf volume, texture, crust and toasting properties. Panelists tasting fresh and day-old breads indicated little or no preference between breads containing sodium chloride and the 1:1 mixture; whereas all panelists disliked the bread containing potassium chloride alone.[1] Similar experiments with hams showed all three salts effective in producing the visible effects associated with curing. Again, ham cured with potassium chloride was unpalatable, while that cured with both ordinary salt and the 1:1 mixture was palatable (unpublished observations).

Implications of extra potassium.

Practicable from the standpoints of taste and physical properties, adoption of sodium-potassium chloride mixtures is also unobjectionable taking into consideration the additional dietary potassium.

As a normal and essential dietary constituent potassium occurs in as high concentration in the human body as sodium (Forbes, 1956). The average intake of potassium according to a survey by Michelson (1962) of teen-age and adult groups in various cities is 4.6 grams (118 mEq) per day with a range among groups of 2.5 to 7.7 grams. The average daily intake as concerns sodium chloride is about 10 grams (containing 4.1 g. or 180 mEq sodium) with large individual variation (Dahl, 1958a, b, c, 1960, 1961b; Meneely, 1961a). Approximately half the salt intake represents that which is in the food as purchased (1.94 g. sodium), while the other half is added during cooking and at the table (Sherman, 1952). On the basis of these reported average intakes, the dietary Na:K gram-atomic ratio is about 1.53.

If the estimated average 5 grams of salt contributed to the diet by cooking and table use were replaced by 1:1 mixture by weight of sodium and potassium chlorides, then the average daily intake of sodium would be reduced from 4.1 to 3.1 grams, the intake of potassium would be increased from 4.6 to 5.9 grams, and the Na:K gram-atomic ratio would change from 1.53 to 0.89. This increase in potassium is well within the normal range cited by Michelson *et al.*, (1962) and the new Na:K ratio would approximate the 0.97 ratio as calculated from the sodium and potassium contents of typical diets as purchased, before being salted in the home (Sherman, 1952).

The increase in potassium intake associated with the use of a 1:1 mixture should pose no toxicological problems. Winkler (1939), Keith (1942), Darrow (1945), and their co-workers have shown that dangers from orally ingested potassium salts are remote except in cases of severe kidney disturbances. Even then, the condition of patients with kidney disease must be extreme before there is any danger from potassium. This was emphasized by Winkler, Hoff and Smith (1941), who stated: "It is unlikely that the conditions necessary for fatal poisoning by oral potassium administration can occur in patients with nephritis so long as urine is being excreted. The relatively slow absorption, the vomiting when large doses are given, the mode of distribution in the body and most important of all, the continued ability of the most severely damaged nephritic kidney to excrete potassium all combine to make such poisoning very difficult to bring about."

Furthermore, the potassium content of this salt mixture may actually aid in reducing the incidence

1. This experiment was done by the W.E. Long Co.—I.B.C., Chicago, Ill., under the direction of Mr. Douglas J. Kirk, Director, Production and Research.

of some forms of hypertension. This suggestion is based on reports from a number of clinicians on the therapeutic uses of potassium for ameliorating hypertension. Addison (1928) suggested treating hypertensive patients with potassium salts as his experiments showed a drop in the blood pressure of patients receiving potassium salts. Priddle (1931, 1962; Nutrition Reviews, 1962) has routinely treated large numbers of hypertensive patients with a low-sodium regimen—supplemented with added potassium salts. He noted that the drop in blood pressure was greater than could be attributed to the salt-restricted diet alone and further that the clinical condition and well-being of the patient was improved.

Animal experiments have corroborated these clinical findings. Gordon (1956) reported a decrease in blood vessel damage as judged by intestinal hemorrhages when hypertensive rabbits were given a 1% potassium chloride solution to drink, although the potassium supplement had no effect on the blood pressure. Bach (1956) and Hilker (1965) and their coworkers changed the dietary sodium-to-potassium ratio in favor of potassium in hypertensive rats and found the rise in blood pressure to be moderated but not prevented. Similar results with hypertensive dogs have recently been reported in Japan (Nose, 1966).

Meneely and coworkers (1957, 1958, 1961b) have demonstrated the protective effects of potassium chloride on rats made hypertensive by feeding of high levels of sodium chloride. While potassium chloride reduced blood pressures only in the most hypertensive rats, the survival times of all hypertensive rats were significantly increased. For example, the fifty-percent survival time for 37 rats fed a ration containing 5.6% sodium chloride and 0.66% potassium chloride was 20 months; for 43 rats fed a ration containing 5.6% sodium chloride and 2.9% potassium chloride, the time was 27 months; for 53 control rats fed a ration containing 1.1% sodium chloride and 0.66% potassium chloride, the time was 22.5 months.[2]

Thus, the incorporation of potassium chloride into ordinary table salt appears worthy of consideration for therapeutic purposes.

Such mixtures provide a palatable seasoning with a reduced sodium content while tasting as salty as ordinary salt. Extra potassium for hypertensives not only appears safe but may have a beneficial effect *per se*. Tobian (1960, p. 308) emphasized this when he stated: "An alteration of the amounts of sodium and potassium in the diet of populations susceptible to hypertension may be the most practical way to decrease the incidence of the disease."

REFERENCES

Achard, C., and Loeper, M., 1901, Sur la rétention des chlorures dans les tissus au cours de certains états morbides. Compt. Rend. Soc. Biol., v. 53, p. 346.

Addison, W.L.T., 1928, The use of sodium chloride, potassium chloride, sodium bromide, and potassium bromide in cases of arterial hypertension which are amenable to potassium chloride. Can. Med. Assoc. J., v. 18, p. 281-285.

Allen, F.M., and Sherrill, J.W., 1922, The treatment of arterial hypertension. Journal of Metabolic Research, v. 2, p. 429.

Ambard, L., and Beaujard, E., 1904, Causes de l'hypertension arterielle. Archives générales de Médecin, v. 1, p. 520.

Bach, I., Handel, M., and Sós, J., 1956, Effect of dietary sodium potassium relations on the experimental renal and neurogenic hypertension of the rat. Acta Physiologica, v. 20, p. 437-443.

Dahl, L.K., and Love, R.A., 1954, Evidence for relationship between sodium (chloride) and human essential hypertension. Arch. Internal Med., v. 94, p. 525-531.

———, 1958a, Sodium intake of the American male: Implications on the etiology of essential hypertension. American Journal of Clinical Nutrition, v. 6, p. 1-7.

———, 1958b, Role of dietary sodium in essential hypertension. J. Am. Dietet. Assoc., v. 34, p. 585-590.

———, 1958c, Salt intake and salt need. I + II. New England J. Med., v. 258, p. 1152-1157, 1205-1208.

———, 1960, Salt, fat and hypertension: The Japanese experience. Nutr. Rev., v. 18, p. 97-99.

———, 1961a, Effects of chronic excess salt feeding. J. Exp. Med., v. 114, p. 231-236.

2. The reader may note for comparison that one month in the life of a rat corresponds roughly to three years in the life of a man, and 1% salt in a rat diet to about 5 g. per day in a human diet.

—–, 1961b, Possible role of chronic excess salt consumption in the pathogenesis of essential hypertension. Am. J. Cardiol., v. 8, p. 571-575.

—–, 1963, Metabolic aspects of hypertension. Ann. Rev. Med., v. 14, p. 69-98.

arrow, D.C., 1945, Body-fluid physiology: The relation of tissue composition to problems of water and electrolyte balance. New England J. Med., v. 233, p. 91-97.

ood and Nutrition Board, 1954, *Sodium Restricted Diets; The Rationale, Complications, and Practical Aspects of Their Use.* Natl. Res. Council Publ. 325. Washington, D.C.

orbes, G.B., and Lewis, A.M., 1956, Total sodium, potassium, and chloride in adult man. J. Clin. Invest., v. 35, p. 596-600.

ordon, D.B., and Drury, D.R., 1956, Effect of potassium on the occurrence of petechial hemorrhages in renal hypertensive rabbits. Circulation Res., v. 4, p. 167-172.

rollman, A., and Harrison, T.R., 1945, Effect of rigid sodium restriction on blood pressure and survival of hypertensive rats. Proc. Soc. Exp. Biol. Med., v. 60, p. 52-55.

ilker, D.M., Wenkam, N.S., and Lichton, I.J., 1965, Blood pressure elevation and renal pathology in rats fed simulated Japanese diets. J. Nutr., v. 87, p. 371-384.

seri, L.T., Boyle, A.J., and Myers, G.B., 1950, Water and electrolyte balance during recovery from severe congestive failure on a 50 milligram sodium diet. Am. Heart J., v. 40, p. 705-800.

eith, N.M., Osterberg, A.F., and Burchell, H.B., 1942, Some effects of potassium salts in man. Ann. Internal Med., v. 16, p. 879-892.

empner, W., 1944, Treatment of kidney disease and hypertensive vascular disease with rice diet. N. Carolina Med. J., v. 5, p. 125-133.

—–, W., 1948, Treatment of hypertensive vascular disease with rice diet. Am. J. Med., v. 4, p. 545-577.

leneely, G.R., Ball, C.O.T., and Youmans, J.B., 1957, Chronic sodium chloride toxicity: The protective effect of added potassium chloride. Ann. Internal Med., v. 47, p. 263-273.

——, and Ball, C.O.T., 1958, Experimental epidemiology of chronic sodium chloride toxicity and the protective effect of potassium chloride. Am. J. Med., v. 25, p. 713-725.

——, and Dahl, L.K., 1961a, Electrolytes in hypertension: The effects of sodium chloride. Med. Clin. N. Am., v. 45, p. 271-283.

——, Lemley-Stone, J., and Darby, W.J., 1961b, Changes in blood pressure and body sodium of rats fed sodium chloride and potassium chloride. Am. J. Cardiol., v. 8, p. 527-532.

Michelson, I., Thompson, J.C., Jr., Hess, B.W., and Comar, C.L., 1962, Radioactivity in total diet. J. Nutr., v. 78, p. 371-382.

Nose, R., 1966, Biochemical studies on experimental hypertension. I–III. Shikoku Acta Med., v. 22, p. 511-532.

Nutrition Reviews, 1962 Sodium, potassium ratios and essential hypertension. Nutr. Rev., v. 20, p. 195-197.

Pike, R.L., 1964, Sodium intake during pregnancy. J. Am. Dietet. Assoc., v. 44, p. 176-181.

Priddle, W.W., 1931, Observations on the management of hypertension. Can. Med. Assoc. J., v. 25, p. 5-8.

——, 1962, Hypertension: Sodium and potassium studies. Can. Med. Assoc. J., v. 86, p. 1-9.

Schou, M., 1957, Biology and pharmacology of the lithium ion. Pharmacol. Revs., v. 9, p. 17.

Sherman, H.C., 1952, *Chemistry of Food and Nutrition.* New York: Macmillan, p. 231.

Tobian, L., 1960, Interrelationship of electrolytes, juxtaglomerular cells and hypertension. Physiol. Rev., v. 40, p. 280-312.

Wheeler, E.O., Bridges, W.C., and White, P.D., 1947, Diet low in salt (sodium) in congestive heart failure. J. Am. Med. Assoc., v. 133, p. 16.

Winkler, A.W., Hoff, H.E., and Smith, P.K., 1939, Factors affecting the toxicity of potassium. Am. J. Physiol., v. 127, p. 430-436.

——, Hoff, H.E., and Smith, P.K., 1941, Toxicity of orally administered potassium salts in renal insufficiencies. J. Clin. Invest., v. 20, p. 119-126.