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Shifting human salty taste preference: Potential opportunities and challenges in reducing dietary salt intake of Americans

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Abstract

Dietary salt reduction of Americans has been a focus of public health initiatives for more than 40 years primarily due to the association between high salt intake and development of hypertension. Despite past efforts, salt intake of Americans has remained at levels well above dietary recommendations, likely due in part to the hedonic appeal of salty taste. As such, in 2010 the Institute of Medicine suggested a strategy of gradual salt reduction of processed foods, the primary source of Americans' dietary salt intake, via an approach intended to minimize impact on consumer acceptability of lower-sodium foods. This brief review discusses the ontogeny and development of human salt taste preference, the role of experience in shifting salt preference, and sources of dietary salt. Our current understanding of shifting human salt taste preference is discussed within the context of potential opportunities for success in reducing dietary salt, and gaps in the research that both limit our ability to predict effectiveness of gradual salt reduction and that need be addressed before a strategy to shift salt preference can realistically be implemented.

Keywords

Salt reduction; sodium; taste; preference

Introduction

Dietary salt reduction of Americans has been a focus of public health initiatives for more than 40 years, primarily due to the role of sodium in development of hypertension and related negative health outcomes (Institute of Medicine 2010a). Despite well-intentioned efforts of the past that have largely relied on modifying consumer behavior, including nutrition labeling and education on the health risks associated with a high salt diet, salt intake of Americans remains at levels well in excess of dietary recommendations—estimated sodium intake of both children and adults is greater than 3,000 mg per day, more than twice that of recommended daily intake levels (Centers for Disease Control and Prevention 2012). For this reason, a 14-member committee was convened by the Institute of Medicine (IOM) in 2008 to recommend strategies to reduce salt intake of Americans to levels consistent with Dietary Guidelines (≤ 2,300 mg per day) (United States Department of Agriculture 2010). The result was the 2010 publication, *Strategies to Reduce Dietary Sodium in the United States*, in which the committee recommended mandatory reduction of salt in processed foods, the primary contributor to Americans' dietary salt intake (Mattes

1990; Mattes and Donnelly 1991), via a strategy of gradual stepwise reductions that would allow the population to adapt to an increasingly less salty food supply, without impacting acceptance of lower-sodium foods. The IOM suggests that in placing the responsibility on the food industry to reduce salt of products before point of purchase, the burden on the consumer to reduce one's own dietary salt intake would be lifted (Institute of Medicine 2010a).

Most preferred level of salt is largely influenced by dietary salt intake; that is, individuals on high sodium diets tend to prefer higher levels of salt (Bertino et al. 1986; Huggins et al. 1992), and individuals on low sodium diets tend to prefer lower levels of salt (Bertino et al. 1982; Blais et al. 1986; Elmer 1988). Though the IOM's suggested strategy is broadly based on this tenet—that reductions of salt in the food environment should naturally be followed by reductions in salt preference over time—their assumption has never been tested directly; as such, further research is required before a successful strategy can realistically be implemented. This brief review discusses the ontogeny and development of human salt taste preference, the role of experience in shifting salt preference, and sources of dietary salt. Our current understanding of shifting human salt taste preference is discussed within the context of potential opportunities for success in reducing dietary salt, and gaps in the research that limit our ability to predict effectiveness of a strategy aimed at reducing liking for an ingredient with powerful hedonic appeal.

Ontogeny and development of salt taste preference

Infants are indifferent to salty taste at birth, but demonstrate an increased preference for saline solutions over water at 4 months of age (Desor et al. 1975), a shift thought to be the result of postnatal development of salt taste receptors (Beauchamp et al. 1986). Though this shift appears to be largely unlearned, additional evidence suggests exposure to salt during this sensitive period may play a role. For example, adult offspring of mothers who experienced severe morning sickness during pregnancy, and therefore probable short-lived sodium depletion during pregnancy, had greater liking for salt than offspring whose mothers experienced little to no morning sickness (Crystal and Bernstein 1995). Similarly, infants exposed to a chloride-deficient formula had heightened preference for salt during adolescence (chloride deficiency is similar to sodium deficiency in terms of hormonal consequences and is thought to exert the same effects on salt taste preference) (Stein et al. 1996). In a separate study, infants exposed to starchy foods that typically contain sodium between 2 to 6 months of age showed increased acceptance for salty taste at 3 to 4 years, including an increased prevalence of behaviors such as licking salt from the surface of foods (Stein et al. 2012).

Beginning at around 4 years of age, children's salt preference is significantly heightened relative to that of adults; in other words, children prefer significantly greater concentrations of salt in both solutions and foods (Beauchamp and Cowart 1990; Mennella et al. 2014). Though the reasons for this age-related difference are not well understood, recent findings suggest the difference may be driven in part by basic biology. In a study of 5 to 10-year-old children, those with a higher percent body fat (a marker of accelerated maturation) preferred a saltier-tasting broth; in addition, salt preference was positively associated with a urinary biomarker for bone growth (Mennella, Finkbeiner et al. 2014). Most preferred level of salt eventually decreases to be similar to that of adults around mid-adolescence (Desor et al. 1975), though the reason for this shift remains unresolved.

The role of dietary experience in establishing salt preference

Salt preferences in adulthood are largely determined by dietary intake of salt. In a landmark study, adult subjects were placed on self-maintained low-sodium diets for a 5-month period. Subjects rated saltiness intensity and pleasantness of saline solutions, soups, and crackers at varying salt concentrations before and during the diet period. Perceived saltiness intensity of crackers increased, and salt concentrations required for optimal pleasantness decreased in both soup and crackers during the diet period, with significant changes in preference first appearing after 2 months. A control group, whose dietary salt was unrestricted during the same 5-month period, experienced no changes in either perceived saltiness intensity or salt preference in solutions and foods (Bertino, Beauchamp et al. 1982). Findings from two similar longitudinal studies were consistent with these results. Subjects on 12-month low-sodium diets experienced a progressive, steady decline in preferred salt concentration in soup, from 0.76 to 0.33% sodium chloride (a 54% difference) at week 24 relative to study baseline. Subjects who did not reduce dietary salt intake did not experience the same shift in salt preference (Blais, Pangborn et al. 1986). In a separate 12-month study, subjects on low-sodium diets had a decreased preference for salt in crackers beginning 3 months after study baseline, and had increased saltiness intensity ratings at the end of the trial; again, control subjects experienced no change in salt preference (Elmer 1988). This association between dietary salt intake and salt preference is further supported by studies demonstrating an increase in most preferred level of salt in foods following increases in salt consumption (Bertino, Beauchamp et al. 1986; Huggins, Di Nicolantonio et al. 1992).

Experience with the taste of a single low sodium food through repeated exposure has been demonstrated to shift hedonic responses to salt, though research to date is limited. In one study, subjects were randomized to one of three groups: a control group that received a 20 ml sample of soup with a salt content similar to a commercially available product, a group that received a 20 ml sample of a no-salt-added soup, or a group that received a 280 ml serving of the no-salt-added soup. Subjects' perceived saltiness intensity, liking, and familiarity of six soups with varying salt concentrations was assessed at a pre-study taste test. This was followed by a period of eight repeated exposures to assigned soups presented in approximately daily intervals, and a post-study taste test identical to the pre-study test. Subjects who received the no-salt-added soup during the exposure period showed increased liking for the soup after three exposures and liked the soup no less than an initially preferred saltier soup at the post-study taste test regardless of sample size received (20 vs. 280 ml), indicating mere repeated exposure to the low-sodium soup was sufficient to shift liking (Methven 2012). In a separate study designed to compare two salt reduction strategies over a 16-week period, subjects were randomized to an abrupt or gradual salt reduction group. All subjects consumed the same high sodium tomato juice for the first 3 weeks of the study (640 mg sodium per 237 ml serving). The abrupt salt reduction group received juice abruptly reduced in salt to a low-sodium target at week 4 (136 mg/serving), and the gradual salt reduction group received juice gradually reduced in salt by weekly 12% decrements, a difference that should have been unnoticeable from week to week (Bobowski and Vickers 2012), to reach the same low-sodium target at week 14. Liking for juice was assessed 3 times weekly over the 16-week period, and in addition, liking for juices of varying salt concentrations was assessed at pre- and post-study taste tests. Regardless of salt reduction strategy, liking for low-sodium juice increased significantly over the course of the exposure period (Bobowski et al. 2015), and a significant percentage of subjects preferred a tomato juice with a lower salt content at the post- relative to the pre-study taste test (Bobowski et al. 2015). These findings suggest it may be possible to reduce most-preferred level of salt in a single food with repeated exposure.

Shifts in salt preference are thought to occur as a result of adaptation to what eventually becomes familiar. Though there is some variation across studies in length of time required to reduce salt preference following a decrease in overall dietary salt intake, findings generally suggest that at least several weeks are needed. Once subjects are habituated to a diet composed of foods low in salt, foods with higher concentrations of salt are perceived as more intense and therefore less pleasant; that is, the low salt diet becomes the context from which higher salt foods are judged (Bertino, Beauchamp et al. 1982; Blais, Pangborn et al. 1986). The opposite is true of acceptance of low sodium foods within the context of higher salt diets, which may explain in part why adherence to a low sodium diet is initially difficult for most. A similar mechanism is thought to drive increases in liking for low sodium foods without changes made to overall salt intake. Assuming most preferred level of salt in a food is developed within the context of the salt level most often consumed, repeated exposure to the same food with a reduced salt content may result in ‘relearning’ a new appropriate level of saltiness through increased familiarity, which in turn, increases acceptability (Methven 2012).

Sources of dietary salt

Salt is integral to food manufacturing—as a processing aid; for its preservative and antimicrobial properties; and for imparting saltiness, enhancing flavor, and suppressing bitterness (Breslin and Beauchamp 1997). Salt added during processing contributes more than 75% to Americans’ total dietary salt intake (Mattes and Donnelly 1991). According to NHANES data, breads and rolls are the primary source of dietary sodium, followed by cured meats, and pizza, among both children and adults (Centers for Disease Control and Prevention 2012).

Discretionary salt use is a minimal contributor to overall dietary salt, estimated at between 2 (Witschi et al. 1985; Sowers and Stumbo 1986; Beauchamp et al. 1987) and 10% (Mattes 1990) of total intake, with an estimated 15% of Americans regularly adding salt to food without tasting (Newson et al. 2013). Despite the ubiquity of salt shakers in homes and restaurants, findings generally suggest the majority of consumers will not overcompensate for reduced-salt content of foods with an increase in discretionary salt use (Liem et al. 2012). In one study, subjects were placed on low sodium diets and given pre-weighed salt shakers to use *ad libitum*. Relative to pre- and post-diet periods, salt shaker use increased among subjects while on low sodium diets; however, after a 50% reduction in dietary salt intake, salt added back to foods with shakers accounted for only 20% of the deficit

(Beauchamp, Bertino et al. 1987). Importantly, subjects in this study had no changes in salt taste preference while on low sodium diets relative to pre- and post-diet periods, a finding inconsistent with previous studies. Researchers hypothesized the reason for this difference was preservation of sensory experience with salty taste through addition of salt on rather than in foods. Despite significant reductions in total salt intake, shifts in preference may not occur without diminished sensory experiences with salty taste.

Shifting human salty taste preference: Research needs

The experts convened by the IOM to contribute to *Strategies to Reduce Sodium Intake in the United States* outlined a series of recommendations to reduce population salt intake that would involve government agencies, the food industry, and public health and consumer organizations; the most notable of these recommendations was gradual reduction of salt in processed foods in a stepwise fashion. In making this recommendation, the IOM committee indicated a number of areas in which research on salt reduction is lacking including what the time course of shifts in salt preference might be following gradual salt reduction, and whether exposure to higher salt foods might interrupt consumer adaptation to a food supply reduced in salt over time. Though progress has been made in the past few years in terms of support for salt reduction—for example, adoption of voluntary salt reduction targets by some food processors, and development of the National Salt Reduction Initiative, a partnership between city and state health departments to coordinate voluntary reduction of salt in packaged and restaurant foods by private companies (Institute of Medicine 2010b)—several important issues should be addressed before effectiveness of strategies for shifting salt preference and intake is determined.

First, whether children's salt preference can be shifted remains unknown. Numerous trials have evaluated the effects of dietary salt reduction on blood pressure among children (He and MacGregor 2006); however, none have assessed the impact of salt reduction on children's salt preference, an age group that prefers higher concentrations of salt than do adults. For children, how a food 'should' taste develops in a context-specific manner beginning at a young age; repeated exposure, building on the familiar, is one of the mechanisms by which children learn (Birch 1999). Though the initial liking for salty taste most likely has innate components, which foods should taste salty and how salty they should taste is learned. Sullivan and Birch's innovative study of 4- to 5-year-old children demonstrated that those repeatedly exposed to salted tofu (a novel food) preferred that version over both plain and sweetened tofu in a post-exposure taste test; the children that learned to associate saltiness with tofu found that particular preparation familiar, appropriate, and therefore acceptable (Sullivan and Birch 1990). Within our current dietary environment replete with foods high in salt, this associative learning may be detrimental, as early familiarization may establish preferences that guide intake of salty foods throughout the lifespan (Birch and Anzman-Frasca 2011). By applying what is known about how preferences are formed, however, liking for low-sodium foods may be promoted through learning via early introduction and repeated exposure, though research is necessary to explore this hypothesis. Until reduction of children's salt preference is examined further, the predicted effectiveness of a population salt reduction strategy cannot realistically include pediatric populations.

Second, though sodium is required by the body in small amounts for nerve conductance and fluid balance, why humans desire and consume salt in the absence of biological need is unknown (Schulkin 1991). Intake of sodium-rich processed foods is likely a contributing factor, however, there are at least two considerations that detract from this explanation: 1) salt intake is relatively consistent across cultures including those with a lower processed food intake than Americans (Intersalt Cooperative Research Group 1988), and 2) there is no data on salt intake prior to the 1950's that might suggest an increase in dietary salt occurred with an increase in consumption of processed foods (Bernstein and Willett 2010; McCarron et al. 2010). In fact, McCarron et. al (2010) have suggested that our current salt intakes are in line with biological requirements, citing sodium reabsorption by the kidneys when intakes fall below 2,760 mg of sodium per day; according to the authors, current dietary recommendations for salt intake are tantamount to ignoring the basic biology of the human. Taken together, there may be other as of yet unresolved reasons for our current salt intakes that could potentially negate a focus on reducing salt added to foods during manufacturing (DeSimone et al. 2013).

Third, reducing sodium intake of a population to no more than 2,300 mg per day has not as of yet been accomplished. Through national education programs and government intervention, both Finland and the United Kingdom (UK) have seen considerable reductions in dietary salt intake of consumers (He and MacGregor 2009); however, it is important to consider both nations within the context of salt intake among Americans to fairly assess potential success of dietary salt reduction in the US. In Finland, a considerable proportion of the reported reduction in salt intake was due to a reduction of salt added to foods at home by consumers (Institute of Medicine 2010a); in the US, discretionary salt is a trivial source of dietary sodium (Beauchamp, Bertino et al. 1987; Mattes 1990). In the UK, the reported salt reduction of 20–30% in most processed foods as of 2009 (He and MacGregor 2009) is within the range typically found to have little impact on acceptability (Janewyatt 1983; Schroeder et al. 1988; Girgis et al. 2003; Malherbe et al. 2003), making it impossible to predict the impact of further salt reductions on food liking and intake. By last estimates of salt intake in both Finland and the UK, salt reduction efforts have resulted in reducing population dietary salt intake to a level approximately equivalent with Americans' current intake (about 3,200 mg/day in Finland as of 2002 and the UK as of 2011) (He and MacGregor 2009; Institute of Medicine 2010a; Department of Health 2011); in other words, reducing dietary salt beyond this level is essentially 'uncharted territory'. As of yet, there is no evidence to suggest that gradual salt reduction might be effective for lowering dietary salt intake further, to levels that could have a significant impact on food palatability.

Our current knowledge of shifting salt preference thus far suggests a strategy focused on reducing salt in processed foods has potential for success due to the strong association between salt intake and preference. However, in light of a paucity of data and a need for continued research, including a randomized controlled trial focused on the IOM's proposed strategy, it may be imprudent to extrapolate from existing relatively short terms studies to conclude that gradually reducing salt in the food supply would be effective for both reducing salt intake and salt preference of an entire population.

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