Reducing Sodium in Foods: The Effect on Flavor

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Abstract: Sodium is an essential micronutrient and, via salt taste, appetitive. High consumption of sodium is, however, related to negative health effects such as hypertension, cardiovascular diseases and stroke. In industrialized countries, about 75% of sodium in the diet comes from manufactured foods and foods eaten away from home. Reducing sodium in processed foods will be, however, challenging due to sodium's specific functionality in terms of flavor and associated palatability of foods (*i.e., increase of saltiness, reduction of* bitterness, enhancement of sweetness and other congruent flavors). The current review discusses the sensory role of sodium in food, determinants of salt taste perception and a variety of strategies, such as sodium replacers (*i.e., potassium salts) and gradual reduction* of sodium, to decrease sodium in processed foods while maintaining palatability.

1. 前言

- NaCl：鹹味刺激物

  Na 提升食物的官能性質：透過增強鹹味、降低苦味、提升甜味與其它調合風味效果。
- 決定個人對鹹味食物的喜好與接受性之因素仍所知有限，但環境因素如食物中鈉含量和飲食習慣應是重要角色。鈉是正常人體運轉必需的，然現行的鈉攝取量遠超出良好健康的建議量。
- 過多鈉的攝取關聯血壓上升，這是心血管疾病的主要成因；推測62%中風與49%冠狀心臟疾病都起因於高血壓。過多鈉的攝取也牽涉許多其它不利健康的影響，包括腸道癌症、降低骨骼礦物質密度和可能糖尿病。

- 研究指出：適度降低15%人口的鈉攝取量可預防過去十年全世界850萬心血管疾病關連的死亡。負面的影響尚包括醫療、照護等經費的付出。
- 不論高鈉消費不利健康的後果與牽連健康照護成本，大多數已開發國家的人仍消費遠超過建議量，使得減鈉成為大眾健康的優先議題。這樣的理由，種種措施被運用降低不同食物的鈉含量，但是，能成功的有限，因減鈉對於滋味性質與風味感受也會造成負面的影響。

2. Physiological Role of Sodium in the Body, Recommended Sodium Intake, and Sodium Consumption Trends

- 在體內，鈉控制細胞外體積(extracellular volume)、 維持酸鹼平衡、神經傳輸、腎功能(renal function)、心輸出量(cardiac output)和心肌細胞收縮(myocytic contraction)。
- 為預防慢性疾病，WHO建議成年人的每日鈉攝取上限須低於87 mmol Na/日 (<5 g食鹽/日)。

  美國的平均值預估140-160 mmol/日 (8.2-9.4 g食鹽/日)，英國為161 mmol/日 (9.4 g食鹽/日)，

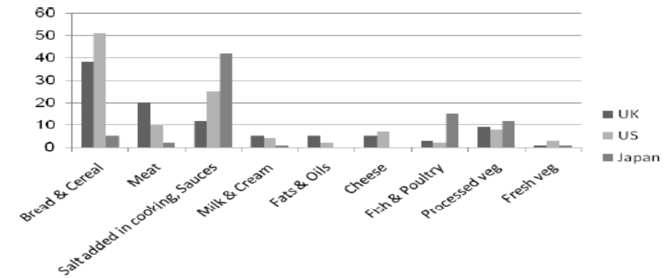
  亞洲國家＞206 mmol/日 (12.0 g食鹽/日)。
- 在西方國家，膳食中的鈉約75%來自加工食品與外食食物。食品的加工常包括為賦與風味或加工目的而添加鈉至食品，例如：鷹嘴豆、甜玉米與碗豆中自然存在的鈉含量很低，加工後增至10倍至100倍(表一)。

Table 1. Comparison of the sodium content of some of the "natural" and processed foods [15].

Food item	Description	Sodium content (mg/100 g)
Beef	Topside, roast, lean and fat	48
	Corned beef, canned	950
Bran	Bran, wheat	28
	Bran Flakes	1000
Cheese	Hard, average	620
	Processed	1320
Chick-peas	Dried, boiled in unsalted water	5
	Canned, re-heated, drained	220
Potato	Raw, boiled in unsalted water	9
	Canned, re-heated, drained	250
Peas	Raw, boiled in unsalted water	Trace
	Canned, re-heated, drained	250
Potato chips	Homemade, fried in blended oil	12
	Oven chips, frozen, baked	53
Salmon	Raw, steamed	110
	Canned	570
	Smoked	1880
Sweet corn	On-the-cob, whole, boiled in unsalted water	1
	Kernels, canned, re-heated, drained	270
Tuna	Raw	47
	Canned in oil, drained	290
	Canned in brine, drained	320

- 文獻記載： 漫長數千年間，人的每日鈉消費量變動不大，只是從遠古時代，用鹽保藏食物； 至現代，鹽的消費轉至加工食品，鹽攝取仍舊過高。
- 在英國與美國，穀類與其產品如麵包、早餐穀品、餅乾和蛋糕貢獻估算鈉總攝取量的30-50% (圖1)，在亞洲國家，在日本大比率的總攝取鈉是來自烹調時所加入的鈉(譬如醬油)。速食也提供每日鈉攝取量的相當比率，例如僅一大塊比薩就貢獻1000 mg鈉或每日鈉攝取上限(2300 mg/日；5.8 g食鹽/日)。

Figure 1. Percentage contribution of food types to average daily intake of sodium [15,24].



3. Flavor Perception

- 風味是一種統合性知覺，我們感覺的是來自獨立感官系統(taste, smell and chemical irritation)輸入的混合，譬如喝橘子口味的飲料，滋味的知覺是由非揮發性醣類及酸類，氣味的知覺受加入飲料提供柑橘特徵的揮發性香氣提供，而化學性刺激則由二氧化碳產生。
- We do not perceive sweetness independently of orange aroma and carbon dioxide tingle; we perceive the sensations simultaneously as an orange flavored soft-drink。如此滋味、氣味和化學性刺激的中央整合使得各知覺之間有充分的機會產生交互作用，移除或降低風味的一種組成分例如甜味，其影響會超越只是甜度的下降，會影響整個風味輪廓(flavor profile)。

4. Taste Perception

- 味覺的進化推測是要能偵測食物中的毒素與營養素，為執行這任務，滋味系統由五種滋味性質呈現：
  甜味—醣類引起，表示食物中的碳水化合物
  鮮味—麩胺酸或其它胺基酸引起，表示食物中的蛋白質
  酸味—質子(protons)引起，表示酸性的食物
  苦味—表示有毒的食物
  鹽味—表示食物中的鈉含量
- 調停滋味知覺之滋味受體細胞(taste receptor cells) 存在整個口腔中，大多數滋味受體細胞是味蕾(taste buds)的構成分，舌頭上有三種型態的乳頭(papillae) (fungiform、foliate 及 circumvallate)，乳頭含有數百個味蕾，每個味蕾由50至150個滋味受體細胞組成，位於滋味受體細胞的頂端處的滋味受體是暴露於口腔內的環境中，化學訊號被轉換成電訊號，經由第7、9及10腦神經纖維傳送至大腦味覺處理區。

- 所感知的滋味由4項不同屬性— quality、intensity、temporal、spatial patterns等表達其特性。

滋味性質 Taste quality is the most important defining feature of taste sensation and is defined as a descriptive noun given to categorize sensations that taste compounds elicit: sweet, sour, salty, bitter and umami.

知覺強度 Perceived intensity is related to the strength of the taste sensation and, when plotted against tasted concentrations, creates a psychophysical function.

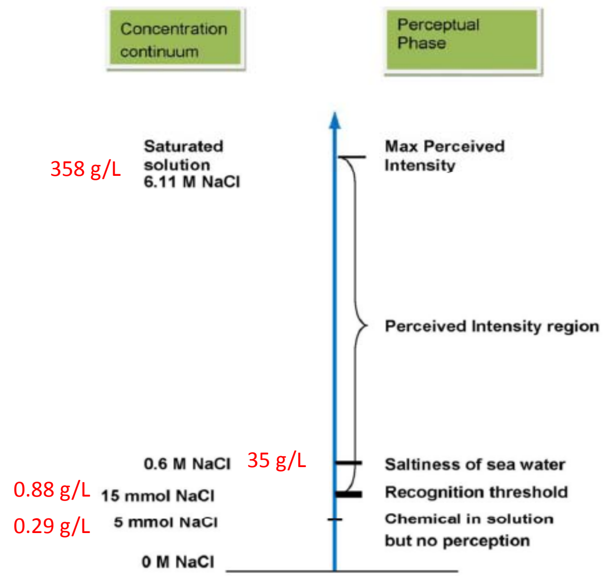
時序樣式 Temporal pattern is used to describe the time course of the taste perception and

空間地形 spatial topography relates to location and localizability of taste sensation.

- 鈉為例，引發的滋味性質(taste quality) 為鹹味(saltiness)，鹹味的強度(intensity) 隨著食物中鈉的濃度而改變，鹹味的時間歷程(time course) 從將鹹味食物入口中、經咀嚼、吞嚥與餘味(aftertaste)而變化，鹹味的發生位置是透過整個口腔內有滋味受體細胞(taste receptor cells)存在之處。
- 僅一項的滋味性質就能用來辨識食物中的鈉，這事實顯示鈉在進化上的重要性。鋰也具有純鹹味，但因毒性而不能核准為食品配料。其它礦物質如鉀在呈味上也帶鹹味部分。
- 鈉作為鹹味的獨家刺激物，可歸就於其獨特的鈉專一性傳導機制包括滋味受體細胞上的上皮細胞鈉通道(epithelial sodium channels; ENaCs)。兩種ENaCs次型存在，其一為鈉專一性的，被低濃度鈉活化，被認為負責鹹味的促進食慾的性質，第二種為多價陽離子可通過的，在高鈉濃度下被活化，被認為負責陽離子令人嫌惡的性質。這是小鼠模式得到的結果，但該機制會不同於人類之理由不多。

- 鹹味知覺的發生始於鈉活化滋味受體上的上皮細胞鈉通道，傳入訊號被送至大腦味覺處理區。在低鈉濃度，傳入訊號過於弱而和同樣但缺鈉的溶液間無有意差，當鈉濃度增加，傳入訊號強度也上升，至一定量時可區別出與水不同，但仍不能確認滋味性質；實際鑑定出鹹味是當鈉濃度增高至不只活化滋味受體，且能產生電脈衝(electrical impluses)，透過感官神經帶至大腦，經解碼後始認定出滋味性質，這即是認知閾值(recognition threshold)。鈉濃度超出認知閾都是可知覺鹹味的範圍，又稱suprathreshold (圖2)。產生鹹味所需的鈉濃度因食品基質而相當變動，在水溶液中比在吐司基質更容易認出50 mM氯化鈉。

Figure 2. Scale diagram of taste perception as concentration increases (adopted from [26]).



5. Taste Interaction

在水溶液中，單一種化合物的濃度上升，知覺強度即增大。但我們的飲食大多是混合食物，而非單一種滋味刺激物。

5.1 Levels of Taste Interactions

滋味化合物之間的交互作用，譬如混合抑制與增效 (mixture suppression and enhancement) 可發生在三種不同的層次：

chemical interactions: 發生於食品基質中，例如麵包中的gluten會吸附鈉，使之無法產生滋味。

oral physiological interactions: 一化合物干擾和第二種化合物有關連的滋味受體細胞或滋味傳導機制。也歸類為 peripheral interactions，因發生於上皮細胞/細胞層次，其例：鈉鹽對苦味的影響，在滋味訊號被送至大腦處理區之前，鈉干擾苦味傳導。

central cognitive interactions: 當傳入訊號被送至大腦的滋味處理區域後滋味刺激物的中樞處理，刺激物用在舌頭不同部位而發生的mixture suppression，即為認知交互作用的一例。

5.2 *Taste Interactions Involving Saltiness*

當滋味性質不同的兩種化合物混合，會發生幾種交互作用，包括非單調的(non-monotonic) (enhancement與suppression兩者)和不對稱性強度(asymmetric intensity)偏移(shifts)。

在食品基質，鈉鹽會影響其它的滋味性質而無關於強度/濃度。例如：

- 氯化鈉與氯化鉀在高濃度下鹹味被抑制，但低濃度氯化鈉與氯化鉀的鹹味被增強。
- 鹹與酸味混合物對稱式地互相影響，在低強度/濃度下每種互被增強，在高強度/濃度下則互被抑制或互無影響。
- 苦味被任何強度/濃度的鈉所抑制，反之，鹹味受苦味的影響程度較低。
- 鈉增進低強度/濃度下的甜味，對中強度/濃度的甜味則各種的影響，對高強度/濃度下的甜味則抑制或無影響。
- 甜味抑制中強度的鹹味。

Figure 3. Schematic review of binary interactions of taste qualities at different levels of intensity/concentration. Adapted with permission from Elsevier [2].

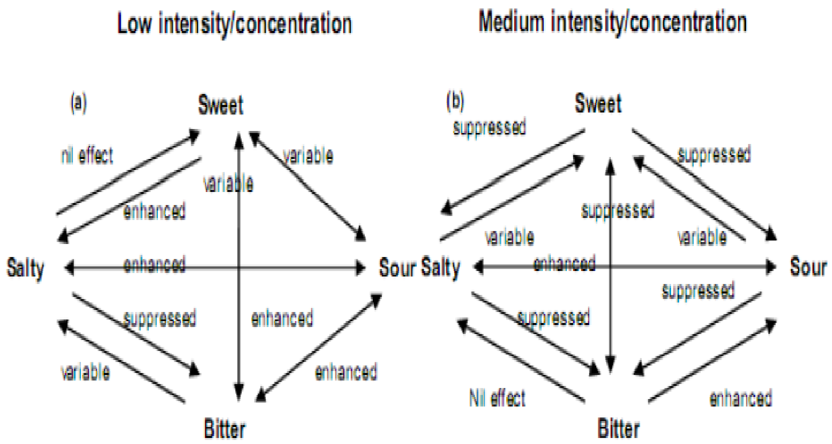
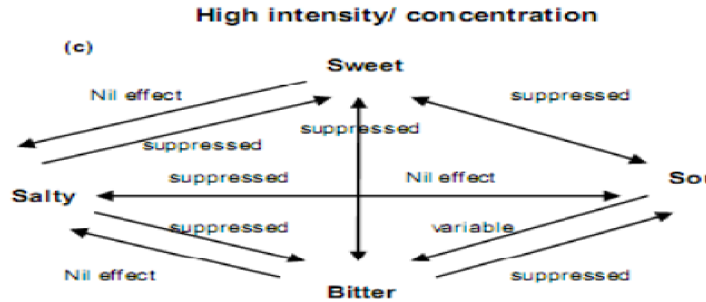


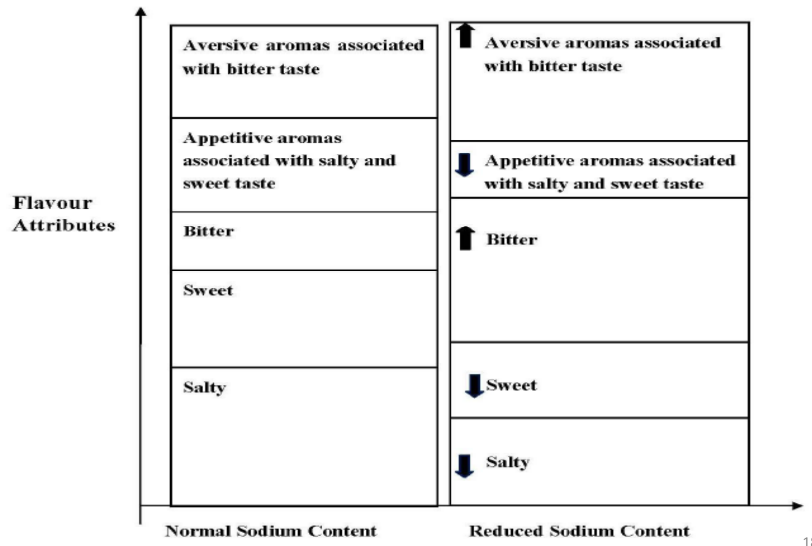
Figure 3. *Cont.*



- 當三種滋味性質混合或當食品基質更為複雜，滋味之間的交互作用更加地複雜。Breslin等(1997)探討鈉(鹹)、蔗糖(甜)、尿素(苦)混合物中彼此間的交互作用，發現：當苦–甜混合中加入鈉，所知覺的苦味受抑制，由於苦味度的降低，所知覺的甜味變強，後者亦即是苦味的減低所知覺甜味之效力變低所致，這交互作用發生於認知的層次。

- 這些的發現和Gillette等(1985)所研究一致： 三種湯中加入氯化鈉，減低苦味、提升甜味。Fuke and Konosu (1991)也指出在合成蟹萃取物中，5’-ribonucleotides的鈉鹽(umami) 可降低苦味而增強甜味。
- 整體上，食物減鈉會有多重的風味影響(圖4)。首要的影響：鹹味變弱 ；另外，苦味增強(由於鈉是苦味抑制劑；移除鈉會使得苦味原被抑制而釋出)；苦味的增強會導致mixture suppression，故而減弱甜味。就滋味喜好性，減鈉會降低 appetitive salt 與甜味，增強令人厭惡的苦味；令人喜歡的鹹味與甜味的減弱，也會導致和這些滋味關聯的令人喜歡的香氣的感知下降。
- Overall, reducing sodium in foods not only reduces perceived saltiness, but is also associated with a wide range of complex taste interactions, which may negatively impact the liking of foods. Without sufficient knowledge about taste interactions the search for sodium replacers and other strategies to decrease sodium in industry sourced foods will be challenging.

Figure 4. Influence of sodium reduction on flavor. The height of the boxes making up total flavor reflects intensity of the named attribute in standard or reduced sodium food [14,35].



6. Factors Affecting Sensitivity and Preference for Salt Taste in Foods

超市貨架上很少陳列低鈉加工食品，這讓消費者循向低鈉飲食實有困難。每個人繼續消費大量的鈉，喜好性就優先朝向多鈉食物，遑論對負面的健康影響已有所了解。影響一個人的鹹味靈敏度、喜好與鹹味食物的選擇之因素所知很少，是否和在口腔的鈉靈敏度和鹹物食物的喜好性之間有關聯。

6.1 Genetic Factors

只2項研究；結論：看不出鹹味靈敏度的遺傳關係，環境因素的影響較大。鹹味喜好性並未探討。

6.2 Environmental Factors

嬰兒與小孩喜歡特定食品的鹹味，被認為是受到6個月齡後吃了一般性鹹味食物之影響，當相較於水，嬰兒能偵測並較喜歡攝食氯化鈉溶液。這認為是經驗所致，鹹味的喜好可說是學習而來而非天生的。

面對高氯化鈉濃度的食物，減鈉膳食的受測者會感覺食物的鹹味變強及對氯化鈉濃度較高食物的喜好減弱。有些研究者探討鈉攝取量和滋味靈敏度及喜好兩者的關連，認為可能是鹽的感官知覺引起。也相信鹹味喜好性的改變是由於鹹味的感官經驗更甚於實際消費的鈉量。

上述的證據仍非定論，且其他研究者指出鹹味靈敏度和鹹味食物的攝食或喜好性之間、或者減鈉膳食的攝取和鹹味食物的喜好性提高之間並無關聯；但這些研究常採用很大的減鈉比率，例如短期間內50%降低。Bertino等(1982)假設兩相式回應(a biphasic response)解釋減鈉，增加鹹味吸引(誘人)的第一相和隨後鹹味喜好性降低，這樣模式可說明在結果上的歧異。

7. Methods of Sodium Reduction

7.1 Sodium Restriction Diet

單純看待減鈉就是告訴消費者他們攝取過多的鈉，且希望他們也改變飲食行為。但透過社區型干預試驗(Community-based intervention trials)的強力輔導，也僅20-40%參加者能減少鈉攝取低於建議上限100 mmol 鈉/天(5.8 mg氯化鈉/天)。

減鈉膳食不太容易維持，因常需改變飲食行為，例如極力選擇低鹽食物，但在超市棚架上這選擇機會很少。廣泛同意：透過降低加工食品的鈉含量，及應用多重感官原理(multisensory principles)譬如促進香氣、讓食物的風味特性最適化相較於只給膳食建議，可更有效地達成減鈉。

7.2 英國的策略--Sodium Reduction by Stealth

英國作法是用隱藏式降低法(stealth reduction methods)，意即在消費者未能查覺的情況下，逐漸減少加工食品中的鹽量。Grigis等(2003)在6周期間逐漸降低白麵包的25%鹽含量，消費者通常不會注意到風味的差異。對食品工業而言，這意味他們能符合減鈉的目標，透過數年期之間逐漸降低產品中的鈉含量。此策略成功地在3年間將超市中的許多加工食品減鈉20-30%。這些成果將被複製再繼續減鈉10-20%，以期符合2012年英國人每日攝取6 g/日的目標。

以隱藏式手段的減鈉具有不需要消費者改變任何行為，也就是傳統方法難以達成的。這方式已使得英國人的氯化鈉攝取量減少約 1 g/天。

7.3 Use of Salt Substitute

減鈉的理想狀況：同樣純粹鹹味的化合物取代，但似是不可能的，因鹹味產生來自鈉對ENaC的專一性。在一些食物產品，氯化鈉取代物譬如氯化鉀、氯化鈣及硫酸鎂被用來代替或增效鹹味，這些化合物確實貢獻一定的鹹味性質，但也提供不需要的餘味譬如苦味、金屬味與澀味，限制目前在食品製造中的使用。

鈉以外的其它陽離子被認為能活化第二型鹹味ENaC，屬非專一性，認為會產生不良的滋味與風味。因此，當使用其它陽離子仍有其吸引力時，特別是鉀，由於增加膳食中的鉀具有附加的健康益處，可用於加工食品的濃度將受限制。

潛在可行性：可知覺的苦味強度與所牽連的不良風味可藉助「苦味封鎖劑」或甜味劑(譬如蔗糖及thaumatin)來減弱。

食品級酸類(food grade acids)可有效增進鈉的鹹味。

- Little and Brinner (1982)改變番茄湯中氯化鈉與檸檬酸含量對滋味喜好性與鹹度的影響。鹹味強度隨著提高檸檬酸濃度而增加，滋味喜好性呈現一雙曲線函數關係，

起初逐漸上升至滋味喜好性最高點(介於0.15-0.3%檸檬酸)，之後急速下降，最高滋味喜好性出現在適度的氯化鈉(0.6%)與檸檬酸(0.3%)濃度。另值得注意的，低鹽湯配檸檬酸可達到甚或超過高鹽湯的喜好度。

- 氯化鈉搭配醋酸/乳酸的混合(Hellemann, 1992)：提高酸的濃度使鹽量不同的所有麵包所知覺的鹹味增強，最高的愉悅評級(pleasantness rating)出現在麵包含適度酸(0.6%)與最高氯化鈉(1.2%)濃度。

7.4 Other Approaches to Sodium Reduction

減鈉會影響食物的整體官能輪廓，減鈉產品可透過香草(herbs)與香辛料(spices)而添加風味。在低鹽產品，麩胺酸一鈉(MSG)是很好的風味增效劑，不會顯著提高產品的總鈉量。Kremer等(2009)用天然釀造黃豆醬油取代各種食品的氯化鈉，當氯化鈉大量減少而用醬油取代，沙拉醬(50%減鹽)、爆炒豬肉(17%減鹽)與湯類(29%減鹽)等仍可接受的。Manabe (2008)指出蒸蛋的17%氯化鈉可加入柴魚取代。

8. Concerns for Food Industry for Sodium Reduction

由於便宜、藉由風味的修飾而提升食物喜好度、其它功能性質等，氯化鈉是廣泛使用的食品添加物。食品加工中需要氯化鈉提供一些功能性，譬如麵糰形成與吸附水以及肉類保存，但一般也認為許多產品的鈉含量都超出加工所需，而主要是要提升官能的作用。對英國食品製造商的一項調查，顯示各式食品中最常標示的氯化鈉功能為「提升風味」，而最常提到減鈉的抱怨為「美味與消費者喜好性」。減鈉可能會減低對食物的喜好，這讓製造廠商維持加工食品現有的鈉含量會有相當的壓力。

8.1. Loss of Palatability and Consumer Acceptance

- 滋味是食品選擇(food choice)的最重要因素之一，人和動物都喜好鹹味，因而大幅度減鈉會使得消費者接受性下降，Grrgis等(2003)指出小幅度減鈉是有效的，當消費者無法感覺出漸進式的減鈉。但當持續降低產品的鈉，無疑就會達到消費者會測出風味輪廓不同的臨界點，食物變得較不受喜歡。

Lucas等(2010)指出a meal component (hash browns)的明顯減鈉(例>50%)，喜好性僅小的下降。故，食物大幅度減鈉是可能的，但理想上鈉所呈現的鹹味需有所取代，讓消費者接受性不受負面影響。

8.2. Texture and Other Quality Characteristics

減低氯化鈉量會影響質地與其它品質特性，包括含水量、油脂量、pH、菌種、各種添加物與加工條件。例如氯化鈉能結合蛋白質與脂肪及保持水分，故低鈉肉糊需要鈉取代物，不僅代替鹹味，也補償減鈉所造成其它功能性的不足。

氯化鈉也會限制酵母的生長而使麵包中的麵筋結構形成，減少麵包的氯化鈉因而導致酵母的成長增加與不完整的麵筋結構，對麵包質地有不良影響。另者，降低乳酪中的氯化鈉會影響菌群活性，然而，減鈉的負面影響並未阻止美國食品業者將不同鹽含量的切達乳酪推上市。

8.3. Preservation and Microbial Safety

鈉降低食品的水活性，故而在各種食品系統中能夠限制並原菌與腐敗微生物的生長。例如加工肉類與乳酪中，氯化鈉限制肉毒桿菌毒素的產生，同樣地，雙醋酸鈉與乳酸鈉限制即食肉類中李斯特菌與乳酸菌的生長；減鈉可能因而出現有害細菌生長的風險與貯藏壽命變短，當鈉減少時，在蒸煮、包裝與貯存溫度上要額外地特別注意，甚者，需要添加其它防腐劑，全新開發的低鈉產品有必要測試微生物安全性與貯藏壽命。

8.4 Other Functions of Sodium

製造低鈉食物除了涉及安全性風險與加工的挑戰，尚有經濟的考量。氯化鈉是相當便宜的，任何代鹽的使用都會增加產品的製造成本，甚且，為尋找適合的代鹽、苦未封鎖劑及或風味增效劑，需要大量人力與經費的研究、開發與消費者測試，當尋求解決減鈉時，食品工業需將食品中鈉的所有功能性都列入考慮。

結論

- 鹹味是許多食物的一項重要官能屬性，而氯化鈉貢獻許多不僅鹹味以外的食物特徵風味。在確保足夠的膳食鈉攝取量對健康至關重要的同時，過量鈉的攝取已知關連高血壓與之後病症的產生，要改變習慣於高鈉飲食人群的膳食鈉含量不容易，意謂這要有些策略。
- 以往加工食品減鈉的嘗試未見成功的部分原因在於失去食物的美味，減鈉的策略之一為用鉀鹽取代鈉，氯化鉀表現弱鹹味，在高濃度下也會出現金屬味與苦味而減低在食物的利用性。加工食品逐漸減鈉這隱藏式手段，即修飾消費者與時推移的鹹味經驗被認為是目前食物減鈉的最佳策略。仍有潛在的障礙，例如食物中鈉在技術面的功能，以及降低消費者喜好性，這可能演變成終止減鈉。

P. A. S. Breslin & G. K. Beauchamp., 1997. Salt enhances flavour by suppressing bitterness. Nature 387, 563

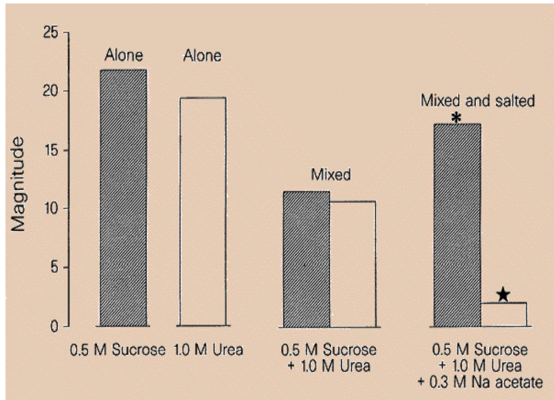


FIGURE 1. The normalized reported magnitude of the taste of various solution mixtures is shown. 在最高濃度下尿素與蔗糖的強度大略相等(左圖)，統計分析顯示：於混合物時，最高濃度的蔗糖與尿素(未加入醋酸鈉) 互相地、約略同等地抑制它們的強度(中圖)。當醋酸鈉加入，也在最高濃度，苦味的強度被大幅度降低，受鈉離子所抑制，反之甜味強度提高至約略溶於純粹的去離子水中的甜味 (右圖)。Relative to binary mixture levels, asterisk denotes increase (*P*<0.0001) and star denotes descrease (*P*<0.0001). These trends were evident for other concentrations tested. Detailed analyses availabel from the authors.

Suppression of Bitterness by Sodium: Variation Among Bitter Taste Stimuli (P.A.S. Breslin and G.K. Beauchamp, Chemical Senses 20: 609-623, 1995)

Abstract

Taste interactions between salts (NaCl, LiCl, KCl, L-arginine:L-aspartic acid, Na-acetate and Na-gluconate) and bitter-tasting compounds (urea, quinine HCl, magnesium sulphate, KCl, amiloride HCl and caffeine) were investigated. In each study binary combinations of three or four concentrations of one bitter compound with four concentrations (0, 0.1, 0.3 and 0.5 M) of one salt were rated for bitterness and saltiness using the method of magnitude estimation.

In most cases, perceived bitterness was suppressed by salts, although the degree of suppression varied. In general, bitterness suppression was not accompanied by an equivalent reciprocal suppression of saltiness. Only MgSO4 and amiloride had suppressing effects on the saltiness of NaCl at the intermediate concentrations and no bitter compound affected the saltiness at the high concentrations of NaCl. Since salt suppressed the bitterness of urea effectively, a detailed analysis of suppression of the bitterness of urea by different salts was conducted.

Those studies indicated that the key component in this effect was the sodium or lithium ion for two reasons: first, all three sodium salts and the lithium salt had a suppressive effect on bitterness, whereas KCl did not; secondly, the effect of a salt on suppression of the bitterness of urea was independent of its perceived saltiness; that is, NaCl, Na-acetate (which is perceived as less salty than NaCl), and Na-gluconate (which is perceived as less salty than Na-acetate) reduced bitterness comparably. These results suggest that there is a major peripheral component to the suppression of the bitterness of urea, and perhaps other bitter tasting compounds, by sodium.

Flavor Effects of Sodium Chloride

Marianne Gillette

Food Technol., June 1985, p47-52&56

There are two approaches to matching the flavor acceptability of salted products in reduced sodium foods:

(1) Add other ingredients to substitute for, but not replace, the salty flavor, thereby maintaining a high flavor intensity but not necessarily a "salty" one. Examples of this include: use of lemon, onion/garlic, vinegar or other acids, and spices and herbs.

(2) Match the flavor by replacing the salty flavor with other, non-sodium containing ingredients which mimic the effects of sodium chloride. There are no known ingredients which thoroughly perform this task, although some ingredients have some "salty" flavor effects (Table 1). These salt substitutes include calcium chloride, magnesium chloride, magnesium sulfate, glutamic acid, potassium glutamate, potassium chloride, and potassium sulfate.

Table 1—**Flavor Descriptors** *for sodium chloride, potassium chloride, and MSG in water*

Characteristic	Sodium chloride (0.2 %)	Potassium chloride (0.2 %)	MSG (0.15 %)
Mouthfeel	Cool Smooth Soft Oily	Astringent	Warm
Saltiness	Salty	Salty	Salty
Sweetness	Sweet	Sweet	Sweet
Balance	Rounded		Rounded
Other			"MSG" Meaty
Off	Metalic Bitter Dishwater	Bitter Metallic Dishwater Plastic	Metallic Chemical Bitter Soapy

Salt Ingredient Evaluations

Name ______________

Date ______________

Please taste the samples from left to right and rate the samples on the following attributes:

Codes = ______ ______ ______

Aroma

Aroma Strength

Other Aroma

Mouthfeel

Fullness

Thickness

Saltiness

Sweetness

Off-Notes

Metallic

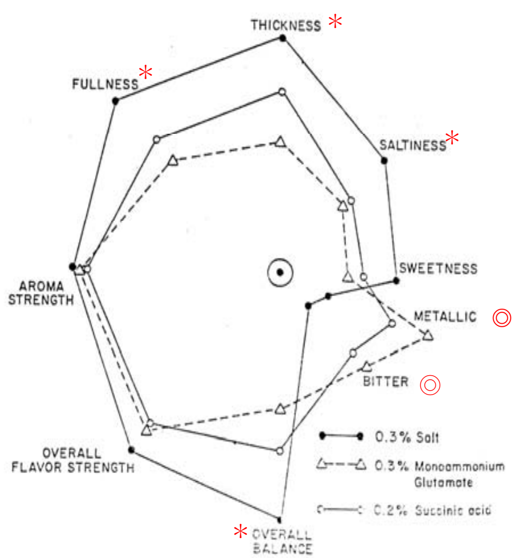
Chemical

Other

Overall Balance

Overall Flavor Strength

Fig. 1—**Ballot Used By Taste Panel** *in evaluating the flavor contribution of sodium chloride*

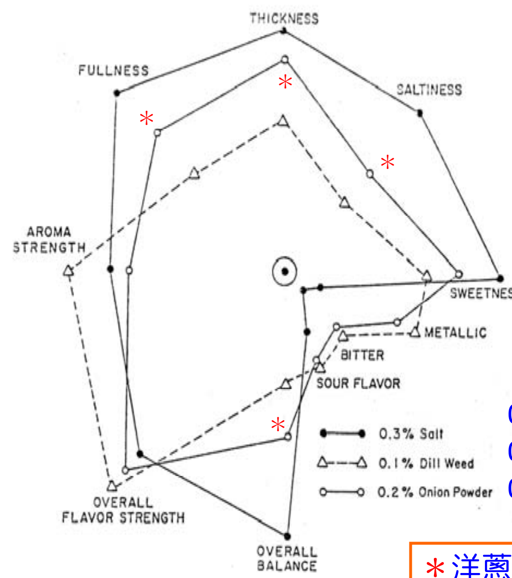


Overall balance

"低鈉" chicken noodle soup

Fig. 2—**Aroma and Flavor Profiles** *for chicken noodle soup with 0.3% salt (sodium chloride), 0.3% monoammonium glutamate, and 0.2% succinic acid added*

0.3% salt
0.3% MSG
0.2% succinic acid



"低鈉" tomato soup

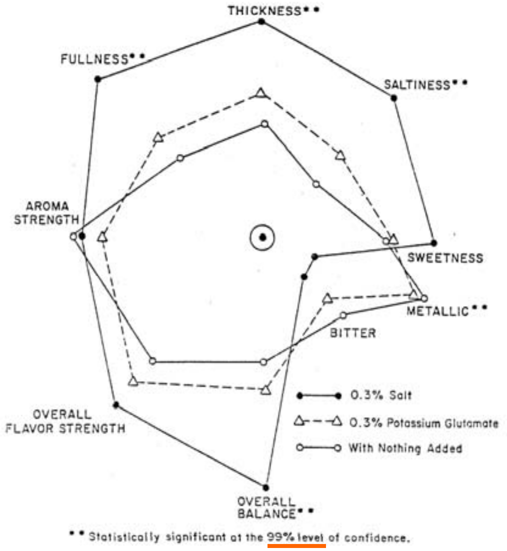
Fig. 3.—**Aroma and Flavor Profiles** *for tomato soup with 0.3% salt (sodium chloride), 0.1% dill weed, or 0.2% onion powder* 蒔蘿

0.3% salt
0.3% 蒔蘿
0.2% 洋蔥粉

＊洋蔥粉組＞蒔蘿組

● 0.3% salt
△ 0.3% 麩胺酸鉀
○ 不添加

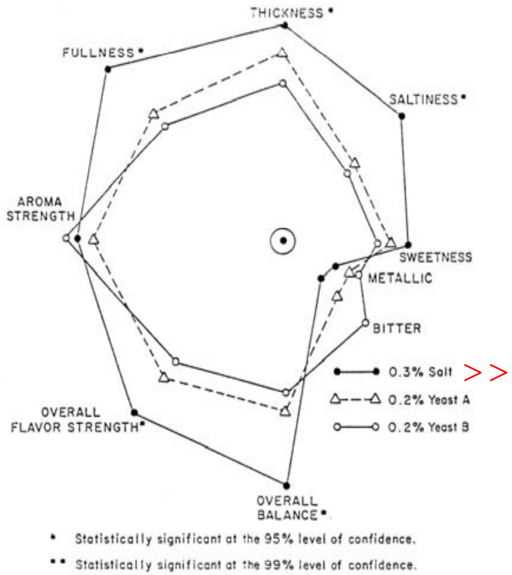
Fig. 4—**Aroma and Flavor Profiles** *for split pea soup with 0.3% salt (sodium chloride), 0.3% potassium glutamate, and with nothing added*



相較於○不添加組，
△組只微幅提高

● 0.3% salt
△ 0.2% Yeast A
○ 0.2% Yeast B

Fig. 5—**Aroma and Flavor Profiles** *for chicken noodle soup with 0.3% salt (sodium chloride) or 0.2% yeast A or B added*



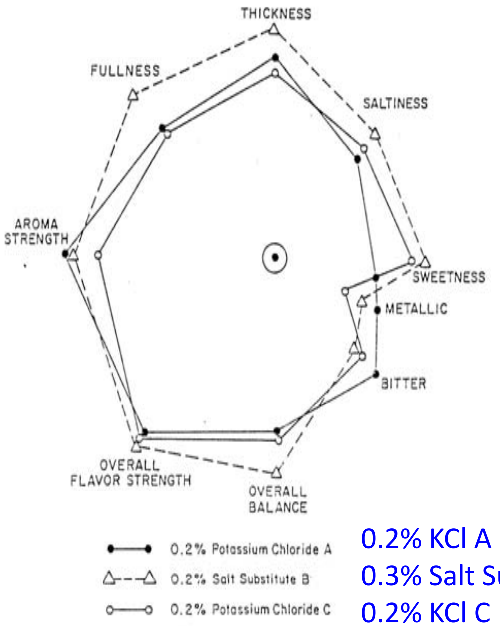


Fig. 6—**Aroma and Flavor Profiles** *for potassium chloride A, salt substitute B, and potassium chloride C at 0.2% in strained peas*

0.2% KCl A
0.3% Salt Substitute B
0.2% KCl C

The results of these evaluations revealed that the addition of sodium chloride to food products does more than simply add a "salty" flavor. The flavor enhancing effects of sodium chloride were very similar for all of the products tested. These effects were grouped into five factors: mouthfeel, sweetness, metallic/chemical off-notes, balance, and saltiness.

Mouthfeel: Sodium chloride increased the perception of "fullness" and "thickness," giving the impression of a less watery or thin product.

Sweetness: The addition of salt to all of the products enhanced the perception of sweetness. In some of the products (tomato soup, split pea soup, and the beef soup) the sweetness was enhanced more than the basic saltiness.

結果顯示：添加氯化鈉至食物，並非單純加入鹹味而已。在所測試的產品，氯化鈉都表現同樣的風味促進作用：mouthfeel口感、甜味、金屬/化學的不佳味調、平衡性與鹹味。

Metallic/chemical/offnotes: In many of the products, a metallic/chemical off-note was decreased or masked by the addition of sodium chloride.

Balance: Overall, the most significant effect that the sodium chloride had upon the various food products was to improve the flavor balance. Flavor balance was "smoothed," "rounded out," and "fuller," and the overall intensity was greater. This factor was partially a result of decreased off-notes, enhanced mouthfeel and sweetness, and increased flavor strength, but also it was the result of a "blending" of flavor perceptions so that

individual flavor notes were less discrete.

Saltiness: The effect on pure saltiness taste perception ranged from subliminal to significant, depending upon the concentration. When presented in the various soups at 0.3%, the "salty" taste per se was not notable. However, in the rice, eggs, and barbecue potato chips, the salt taste was distinct.

The potassium-chloride-based salt substitutes also enhanced sweetness, but did not enhance mouthfulness or flavor balance in the manner that sodium chloride did. Additionally, the potassium-chloride-based substitutes imparted a bitter, chemical, metallic off-note.

In summary, a panel was trained to recognize the effects of sodium chloride on a variety of foods. The panel categorized these effects into five main factors: sodium chloride was found to enhance mouthfeel, sweetness, balance, and saltiness, while decreasing or masking off-notes. Potassium chloride based salt substitutes did not enhance mouthfeel or balance and significantly increased bitter/metallic off-notes.

The panel has been extremely valuable in their evaluations of various salt substitutes (Fig. 6) and blends thereof, giving clear direction to the food chemists in their evaluations of competitive products and for new product formulation.