CARLA SARAIVA GONÇALVES

DESENVOLVIMENTO DE MIX DE SAIS COM REDUZIDO TEOR DE SÓDIO: OTIMIZAÇÃO E CARACTERIZAÇÃO SENSORIAL TEMPORAL (TDS E TI)

LAVRAS – MG

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Dissertação apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Ciência dos Alimentos, área de concentração Ciência dos Alimentos, para a obtenção do título de Mestre.

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APROVADA em 19 de Agosto de 2013.

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LAVRAS - MG

2013

Ao meu noivo, Diego, por toda a ajuda,
amor e companheirismo.

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RESUMO GERAL

A redução de sódio em alimentos tem atraído muita atenção, uma vez que os estudos indicam uma correlação entre a ingestão de sal na dieta e algumas doenças. Métodos de otimização são úteis dentro da ciência sensorial como uma maneira de obter um resultado sob um conjunto específico de condições para que seja possível compreender questões que proporcione potenciais fórmulas. Neste estudo, avaliou-se a concentração ótima do cloreto de sódio na sopa de batata, usando a escala ideal, e a magnitude equivalente de diferentes sais no que diz respeito ao cloreto de sódio. Determinou-se o equivalente de sal em comparação com o sal de cloreto de sódio para cada substituto estudado e avaliou-se a sua salga por meio do método de estimação da magnitude. O delineamento Plackett-Burman foi utilizado para eliminar variáveis no estudo. A otimização dos parâmetros de aceitação do mix de sal foi alcançada pelo delineamento de mistura. O perfil de sabor das misturas com redução de cloreto de sódio e os substitutos foram avaliados por meio de análises sensoriais temporais (TDS e TI). A concentração de cloreto de sódio considerado ideal em sopa de batata foi de 0,9%. Por meio do delineamento Plackett-Burman observou-se que os substitutos de cloreto de sódio (fosfato de potássio e lactato de potássio) possuem grande rejeição devido ao seu sabor desagradável, sendo esses sais eliminados nas etapas seguintes. Utilizando o método de estimativa de magnitude, foi determinado que, para promover um sal equivalente ao sal ideal (cloreto de sódio a 0,9%), cloreto de potássio e glutamato monossódico, deve ser adicionado à sopa de batata, em concentrações de 1, 2146% e 4, 4314%, respectivamente. Um sal otimizado foi sugerido com 25% de cloreto de sódio, 10% de cloreto de potássio e 65% de glutamato monossódico. No perfil sensorial dos substitutos de sal testados, um gosto amargo foi percebido na sopa de batata com cloreto de potássio e gosto umami foi dominante na sopa de batata com glutamato monossódico. As três misturas testadas foram de 25, 10 e 65%; 50, 10 e 40%; e 75, 15 e 10% de cloreto de sódio, cloreto de potássio e glutamato monossódico, respectivamente. As misturas com cloreto de sódio a 75% apresentaram maiores Imax (5, 3182) seguido de mistura com 25% (4, 5477) de cloreto de sódio e 50% (3, 9914) de cloreto de sódio.

Palavras-chave: Cloreto de Sódio. Cloreto de Potássio. Glutamato Monossódico.

GENERAL ABSTRACT

Reducing sodium in foods has attracted much attention since studies indicate a positive correlation between salt intake in the diet and a few diseases. Optimization methods are useful in sensory science as a way of obtaining a result under a specific set of conditions in order to allow the understanding of issues which provide potential formulas. In this study, we evaluated the optimum concentration of sodium chloride on potato soup, using the ideal range, and the magnitude equivalent of different salts regarding sodium chloride. We determined the salt equivalent compared with sodium chloride salt for each studied substitute, evaluating their salting through the magnitude estimation method. The Plackett-Burman design was used to eliminate variables in the study. The optimization of the parameters of acceptance of the salt mix was achieved by mix design. The flavor profile of the mixtures with reduced sodium chloride and the substitutes were evaluated by temporal sensory analysis (TDS and TI). The concentration of sodium chloride considered ideal in potato soup was of 0.9%. Through the Plackett-Burman experimental design we observed that substitutes for sodium chloride (potassium phosphate and potassium lactate) have high rejection due to its unpleasant taste, these salts being eliminated in the following stages. Using the magnitude estimation method, we determined that, in order to promote a salt equivalent to the ideal salt (sodium chloride 0.9%), potassium chloride and monosodium glutamate must be added the potato soup in the concentrations of 1.2146% and 4.4314%, respectively. An optimized salt was suggested with 25% sodium chloride, 10% potassium chloride and 65% of monosodium glutamate. In the sensory profile of the tested salt substitutes, a bitter taste was perceived in the potato soup with potassium chloride, and a umami taste was dominant in the potato soup with monosodium glutamate. The three tested mixtures were 25, 10 and 65%; 50, 10 and 40%, and 75, 15 and 10% of sodium chloride, potassium chloride and monosodium glutamate, respectively. The mixtures with sodium chloride at 75% presented higher Imax (5.3182), followed by the mixture with 25% (4.5477) and 50% (3.9914) of sodium chloride.

Keywords: Sodium chloride. Potassium chloride. Monosodium glutamate.

SUMÁRIO

PRIMEIRA PARTE

1 INTRODUÇÃO

O cloreto de sódio é tradicionalmente utilizado como um aditivo e é adicionado a produtos alimentícios para melhorar o sabor. Ele também atua como conservante, conservando os alimentos por mais tempo (GUINEE, 2004).

Organização Mundial de Saúde (WHO) recomendou em 1990 uma limitação da ingestão diária média de NaCl a 6 g para adultos (WORLD HEALTH ORGANIZATION - WHO, 1990). Dezessete anos depois, a OMS repetiu essa advertência e recomendou uma ainda menor ingestão diária de sódio de 5 g por dia (WHO, 2007). Por conseguinte, a redução do teor de NaCl em produtos alimentícios tornou-se um importante desafio para a indústria de alimentos. Ainda mais que uma diminuição do teor de NaCl é muito frequentemente associado a uma diminuição na aceitação dos consumidores (KREMER; MOJET; SHIMOJO, 2009).

Uma pesquisa do Ministério da Saúde (BRASIL, 2011) observou que o brasileiro consome, em média, 12 g de cloreto de sódio/dia (4800 mg de Na/dia) sendo este consumo maior que o dobro do limite considerado saudável pela Organização Mundial de Saúde (WHO), o que corresponde a aproximadamente 2000 mg de sódio por dia.

Há relatos que o uso excessivo de sódio na dieta está associado com hipertensão, que por sua vez associa-se com as doenças cardiovasculares. Um relacionamento entre o consumo de sódio, osteoporose e a incidência de pedras nos rins também foi encontrado (HEANEY, 2006; SIHUFE; ZORRILLA; RUBIOLO, 2003; WHO, 2007).

Portanto, os consumidores estão procurando formas de diminuir a ingestão diária de sódio, aumentando assim a demanda por produtos com reduzido teor de sódio em alimentos (APPEL; ANDERSON, 2010).

Dessa forma, o Ministério da Saúde e a indústria de alimentos fecharam acordo para reduzir o teor de sódio em 16 categorias de alimentos processados (macarrão instantâneo, batata frita e batata palha, refrigerantes light e diet à base de cola, pão francês, bolos prontos, misturas para bolos, salgadinhos de milho, biscoitos, embutidos (salsicha, presunto, apresuntado, hambúrguer, empanados, linguiça, salame e mortadela), caldos e temperos, margarinas vegetais, maioneses, derivados de cereais, laticínios (bebidas lácteas, queijos e requeijão) e refeições prontas (pizza, lasanha, papa infantil salgada e sopas) nos próximos quatro anos. A previsão é de que haja uma redução gradual da taxa de sódio para ser cumprida até o final do ano de 2012 e, depois, intensificada nos dois anos seguintes.

Desse modo, a substituição de cloreto de sódio por outros sais (lactato de cálcio, lactato de potássio, KCl etc.) é considerada uma abordagem alternativa para reduzir o teor de sódio nos alimentos. Determinar o melhor substituto para o cloreto de sódio em um produto requer vários testes sensoriais. Quando substituímos determinado ingrediente é importante saber qual substituto e qual a concentração do substituto melhor equivale à intensidade de sabor e às características do produto original. Para tanto, utiliza-se testes sensoriais utilizando escala do ideal e determina-se a potência de salga de diferentes sais (VICKERS, 1998).

Há grandes dificuldades para se encontrar substitutos eficientes para o NaCl, uma vez que há várias razões para se utilizar esse sal nos alimentos. O uso do NaCl nos alimentos tem função nas categorias: processamento; sensorial; e preservação. Em alguns casos, ele executa todas as três funções, e em muitas situações, a distinção entre elas não é clara, por exemplo, o papel do sal na conservação de queijo tem também um efeito sobre o sabor do produto final (HUTTON, 2002).

Levando em consideração o elevado consumo de sal e suas respectivas influências na prevalência de hipertensão arterial, aumento dos casos de doenças crônicas não transmissíveis como obesidade, doenças cardiovasculares, hipertrigliceridemia e diabetes, aumenta-se a demanda por novos produtos com redução de sódio que sejam aceitos pelos consumidores.

Diante desse contexto, o objetivo com esse trabalho foi desenvolver um mix de sais com reduzido teor de sódio que atenda a nova demanda dos consumidores, por meio da oferta de um novo produto substituinte do NaCl, com reduzido teor de sódio, saudável, com qualidade sensorial, seguro e que traga benefícios para a saúde dos mesmos.

2 REFERENCIAL TEÓRICO

2.1 Desenvolvimentos de Novos Produtos

O desenvolvimento de novos produtos (DNP) nas economias de mercados dinâmicos é fator essencial para a sobrevivência das empresas. Está em estreita relação com as necessidades e tendências ou modas de consumo da massa consumidora, o que traz como consequência a necessidade de respostas rápidas das indústrias de alimentos às mudanças do mercado consumidor (BARBOSA et al., 2010).

A indústria de alimentos no Brasil tem utilizado como principal estratégia de marketing a conquista das preferências dos consumidores pela diferenciação dos produtos, ato que requer gastos significativos em técnicas de processamento, marketing e pesquisas para identificação dos novos desejos e necessidades dos consumidores. As empresas buscam primordialmente oferecer atributos adicionais ao consumidor por meio da diferenciação do produto, de forma a obter maior grau de competitividade no mercado em que atuam pela ampliação da gama de produtos que ofertam, sendo que, em alguns casos, obtém preço prêmio portal estratégia (GONSALVES, 1997).

2.1.1 Cloreto de Sódio

A definição de sal para consumo humano refere-se à “NaCl cristalizado, extraídos de fontes naturais, com a adição obrigatória de iodo". O sal deve ser apresentar sob a forma de cristais brancos, com grânulos uniformes, livres de odores e possuir o seu sabor característico salina. Minerais (antiumectante) podem ser adicionados ao sal, por os limites estabelecidos por lei (BRASIL, 2000).

O efeito antimicrobiano do NaCl é atribuído principalmente à sua capacidade de reduzir a atividade de água nos alimentos, ajudando a prevenir a deterioração e manter certos alimentos seguros para o consumo (CRUZ et al., 2011).

Sal de cozinha, NaCl, contém sódio em sua composição, o sódio é o componente mais abundante nos fluidos extracelulares e permite o transporte de nutrientes (GREELEY, 2012). A sua ingestão é essencial, pois contribui para o mecanismo de regulação da pressão arterial, o transporte de água intracelular, transmissão de impulsos nervosos, contração muscular, regulação da pressão osmótica e equilíbrio ácido-base (VIEGAS, 2009).

O sódio é um nutriente essencial que o corpo humano não produz. Uma ingestão insuficiente de sódio pode afetar negativamente o sistema nervoso e o muscular uma vez que o mesmo auxilia a absorção de potássio pelo organismo, sendo um componente do ácido gástrico e que aumenta a capacidade do sangue em transportar dióxido do carbono (BRODY, 1999). Entretanto, quantidades excessivas têm consequências, como o aumento da pressão arterial (JIMÉNEZ-FLORES, 1997).

A crescente oferta de alimentos industrializados e com preços baixos (ricos em gorduras, açúcares e sódio) associado à redução da atividade física, resultou em alterações dos padrões do estado nutricional, com um aumento da prevalência de sobrepeso e da obesidade e a diminuição da incidência de desnutrição, caracterizando assim a transição nutricional da população brasileira (BRASIL, 2010).

Essa mudança no perfil nutricional da população brasileira gera um grande aumento das doenças crônicas não transmissíveis como obesidade, doenças cardiovasculares, diabetes e câncer, que nas ultimas décadas, passaram a liderar as causas de óbito no Brasil (BRASIL, 2010).

Produtos industrializados são os que mais contribuem para os altos níveis de ingestão de sódio por parte da população como observado na Figura 1.

Uma pesquisa do Ministério da Saúde (BRASIL, 2011) observou que o brasileiro consome, em média, 12g de cloreto de sódio/dia (4800 mg de Na/dia). O limite considerado saudável pela Organização Mundial de Saúde (OMS) não passa de 5 g de cloreto de sódio, o que corresponde a aproximadamente 2000 mg de sódio por dia.

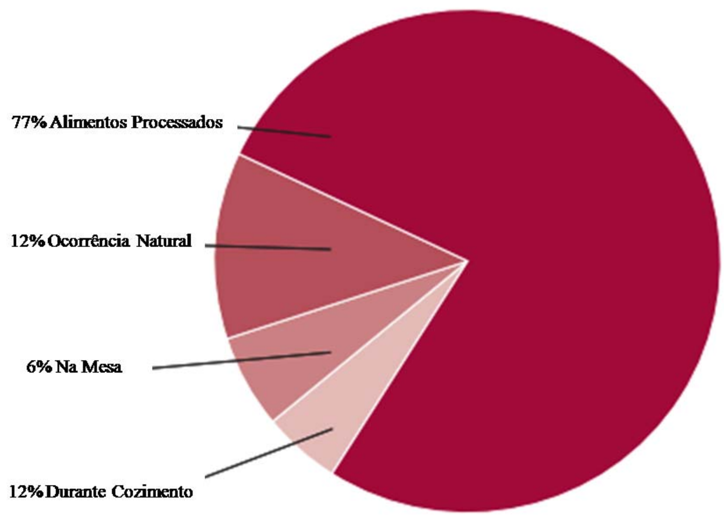

Figura 1 Contribuição dos alimentos para consumo de sódio da população mundial

Fonte: United States of Department of Health and Human Services - USDHJS (2005)

Dessa forma, o Ministério da Saúde e a indústria de alimentos fecharam acordo em abril de 2011 para reduzir o teor de sódio em 16 categorias de alimentos processados (macarrão instantâneo, batata frita e batata palha, refrigerantes light e diet à base de cola, pão francês, bolos prontos, misturas para bolos, salgadinhos de milho, biscoitos, embutidos (salsicha, presunto, hambúrguer, empanados, lingüiça, salame e mortadela), caldos e temperos, margarinas vegetais, maioneses, derivados de cereais, laticínios (bebidas lácteas, queijos e requeijão) e refeições prontas (pizza, lasanha, papa infantil salgada e sopas) nos próximos quatro anos. O compromisso do Ministério da saúde prevê uma redução gradual da taxa de sódio para ser cumprida até 2012 e, depois, intensificada nos dois anos seguintes.

2.1.2 A importância tecnológica do sal

Na indústria de alimentos, o sal é utilizado para uma grande variedade de funções técnicas, convertendo-se num dos ingredientes mais utilizados na produção de alimentos. De acordo com Trinderup (2011) o sal é fundamental para ressaltar e aumentar de forma natural o sabor dos alimentos. Além desta qualidade organoléptica que o fez universalmente popular, o sal tem outras muitas propriedades:

a) A capacidade do sal como conservador e preservador foram fundamentais para o desenvolvimento humano ao longo da história, uma vez que permitia a conservação dos alimentos;
b) Nos processamentos de alimentos, o sal atua como aglutinante de outros ingredientes;
c) O sal funciona como substância que permite controlar os processos de fermentação de determinados alimentos;
d) O sal é utilizado para dar textura aos alimentos, para que resultem mais agradáveis ao tato e visualmente mais atrativos e apetitosos;

e) O sal é utilizado para potencializar a cor de muitos alimentos, fazendo-os mais agradáveis à vista;
f) O sal é um agente usado para desidratar e amolecer muitas matérias-primas da alimentação.

Em produtos vegetais, o sal é usado principalmente como conservante (LÜCK; JAGER, 2000) e um agente de amolecimento (BUREN, 2006) e também para atingir o processo de salga a seco (PANAGOU, 2006) ou para o processo de fermentação. Em alguns produtos de origem vegetal, o sal não desempenha um papel direto como conservante, pois um baixo nível de sal inicia um processo de crescimento competitivo e seletivo microbiológica, favorecendo o desenvolvimento de bactérias lácticas (BAUTISTA-GALLEGO et al., 2010; LÜCK; JAGER, 2000).

Dentre os produtos lácteos, o mais importante envolvendo o uso de sal é o queijo. Geralmente o sal é adicionado para controlar o crescimento de bactérias do ácido láctico e para prevenir o crescimento microbiano indesejável, também tem uma função secundária que é fornecer sabor adicional de forma branda ao queijo (ROWNEY et al., 2003).

Já em produtos cárneos, o sal está envolvido na retenção de água, firmeza e desenvolvimento do sabor, influencia no crescimento microbiano, atividade enzimática e não enzimática (PUOLANNE; RUUSUNEN; VAINIONPÄÄ, 2001).

2.1.3 Substitutos para o Cloreto de Sódio

O cloreto de potássio é provavelmente o substituto do sal mais comumente utilizado nos alimentos. A grande desvantagem da sua utilização reside no sabor amargo e metálico que confere ao produto final (DESMOND, 2006).

A substituição parcial de NaCl por KCl parece ser a melhor alternativa para reduzir o teor de sódio. O cloreto de potássio apresenta aproximadamente 80% da capacidade de salgar, mas possui sabor amargo. Para contornar o problema, outros ingredientes, como o cloreto de sódio, autolisado de levedura, nucleotídeos e temperos podem ser adicionados para maximizar o sabor e funcionalidades. O cloreto de potássio é comercializado por várias empresas e em diferentes combinações, sendo que as mais conhecidas contêm 780 mg/g de KCI e 200 mg/g de NaCI; e 19,6 g NA/100 g e 26 g de K/100 g (TRINDERUP, 2011).

Sais de ácidos orgânicos, tais como lactato de sódio, lactato de potássio ou diacetato de sódio também são usados em substituição ao NaCl para prolongar a vida útil e para proporcionar um melhor controle de bactérias patogênicas de origem alimentar. Lactato e potássio e lactato de cálcio são igualmente eficazes como lactato de sódio no controle do crescimento de bactérias em carne e produtos de atividades antilisterial (DEVLIEGHERE et al., 2009).

Além das opções já relatadas, há também um grande interesse em adicionar intensificadores de sabor, compostos que ativam os receptores na boca e garganta, ajudando a reduzir o nível de sal (BRANDSMA, 2006). O glutamato monossódico é um realçador de sabor mais comumente utilizados pela indústria de alimentos, especialmente na produção de aperitivos (TRINDERUP, 2011).

Os substitutos de sal podem conter sílica coloidal ou silicatos (menos de 1% m/m individualmente ou combinados), diluentes que sejam considerados seguros (açúcares, farinhas de cereais) e iodo na concentração determinada pelo país onde o produto é comercializado (TRINDERUP, 2011).

Entretanto, essa técnica de substituição levanta diversas questões como a possível redução do sabor salgado, a eventual introdução de gosto metálico, amargo e adstringente, cores e texturas anômalas, a ação dos cátions diferentes a atividade enzimática durante o processo de secagem curado; a quantidade de sal necessária para obter um produto seguro, microbiologicamente estável, e o tempo de salga necessário, quando se utiliza uma mistura de diferentes sais (ALIÑO, 2009).

2.1.4 Análise Sensorial

a) Importância da analise sensorial

A avaliação sensorial é um conjunto de métodos e técnicas que permitem perceber, mostrar, medir, analisar, identificar e interpretar as reações das propriedades sensoriais dos alimentos mediante os órgãos dos sentidos da visão, olfato, gosto, tato e audição (GULARTE, 2002).

É uma ferramenta imprescindível para a indústria alimentícia, pois por meio dela pode-se determinar a qualidade de um determinado produto, avaliar a percepção e a reação humana diante dos atributos de um alimento, analisar se o produto avaliado tem qualidade superior aos produtos concorrentes, verificar se formulações diferentes são melhores ou piores que a original, determinar as características sensoriais do produto como atributos de sabor, textura, cor, odor e intensidade e prever se o consumidor irá gostar do produto, com base em suas características sensoriais (GULARTE, 2002).

Por meio da análise sensorial é possível determinar a aceitabilidade e a qualidade dos alimentos, com auxílio dos órgãos humanos dos sentidos. Para avaliar a qualidade devem-se levar em conta as propriedades sensoriais aceitáveis como essenciais no momento da venda e consumo do produto (GULARTE, 2002).

A análise sensorial como método científico usa testes sensoriais realizados por analistas sensoriais, que participam em cursos de treino e são escolhidos com base nas suas aptidões. Porém, as provas também podem ser efetuadas de modo não científico, por julgadores organolépticos, sem qualquer tipo de treino, que confundem os testes de qualidade com avaliações hedônicas e permitem que a sua opinião seja influenciada (CARPENTER; LYON; HASDELL, 2000).

2.1.5 Análise sensorial e os Sais

Muitas substâncias podem ter seu sabor salgado avaliado pela análise sensorial, mas apenas NaCl oferece o que é realmente reconhecido como puro sabor salgado. Além disso, uma das mais importantes funções do sal é criar uma base para a percepção de outros sabores, ou seja, ele funciona como um potenciador de gosto em alguns casos e inibidor em outras, além de promover maior percepção de aromas (KILCAST; RIDER, 2007).

Quando há uma substituição do cátion ou ânion de NaCl com um composto de alto peso molecular, isso gera menos intenso sabor salgado e maior sabor ácido (GUARDIA et al., 2006). Ruusunen e Puolanne (2005) mostraram que é possível reduzir o teor de sódio em produtos cárneos por substituição de fosfato de sódio com fosfato de potássio.

A percepção do sabor salgado de NaCl é atribuída tanto ao cátion (70-85%) ou ao ânion (30-15%) (MATTES, 2001).

Em comparação com sódio, outros cátions (potássio, magnésio e cálcio) dão acidez e percepção menos salgada. Em comparação com o cloreto, outros anions (fosfatos e citratos) interferem mais diretamente no paladar, diminuindo a salinidade e deixando sabor residual metálico devido ao fosfato (MOOSTER, 1980).

A concentração ótima de sal (cloreto de sódio) pode ser avaliada por meio de testes sensoriais utilizando a escala do ideal (Just-about-right scale) e por meio da potência de salga de diferentes sais e seus possíveis substitutos por meio da Lei de Stevens ou "Power Function" (SOUZA et al., 2011; VICKERS, 1988).

2.2 Método da escala do ideal

Entre os métodos sensoriais existentes para se medir a quantidade ideal de um determinado componente a ser adicionado para melhorar a aceitação e preferência de um produto, a escala do ideal é o método afetivo mais aplicado, tanto devido à confiabilidade e validade de seus resultados quanto à simplicidade de aplicação. Nesta análise, a equipe de julgadores avalia as amostras e registram suas respostas em escala específica, o quão ideal estas amostras encontram-se, em relação ao atributo que se deseja avaliar (por exemplo, doçura, textura e outros) (SOUZA et al., 2011; VICKERS, 1988).

Os dados obtidos são então submetidos à análise estatística por meio de gráfico de distribuição das respostas sensoriais (em porcentagem), em função da concentração do componente que está variando e, também, por regressão linear simples entre os valores hedônicos e a concentração do componente que está variando (CARDOSO; BATTACHIO; CARDELLO, 2004; SOUZA et al., 2013).

Com a aplicação da análise de aceitação, com a escala do ideal, é possível transformar dados subjetivos em objetivos e obter informações importantes sobre a concentração adequada de um composto a ser adicionado em um alimento ou bebida (CARDOSO; BATTACHIO; CARDELLO, 2004; SOUZA et al., 2011, 2013).

2.3 Método da Escala de Magnitude

Quando precisamos substituir algum ingrediente alimentar quer seja em partes quer totalmente é necessário saber o quanto o novo ingrediente equivale ao usual. Existem varias metodologias para a obtenção destas informações, porém o método mais aplicado é o de estimação da magnitude e representação gráfica dos resultados normalizados, por meio da Lei de Stevens ou "Power Function" (MOSKOWITZ, 1970; STONE; OLIVER, 1969).

A equivalência de sal é uma etapa preliminar essencial para determinar a quantidade de um substituto a ser adicionado em um produto, em mesma equivalência do cloreto de sódio, a fim de obter a mesma percepção de sal pelos consumidores. Entretanto, a percepção de salgado é influenciada por vários fatores (SOUZA et al., 2011).

No método de estimação de magnitude descrito por Stone e Oliver (1969), os julgadores recebem uma amostra referência com uma intensidade de valor arbitrário, por exemplo, 100, seguida de uma série de amostras em ordem casualizada, com intensidades maiores ou menores do que a referência. Os julgadores deverão estimar a equivalência de sal atribuindo notas às amostras em relação a uma amostra referência. Se a amostra, por exemplo, tiver o dobro da intensidade de sal em relação à referência, deverá ter o valor 200, se for a metade, 50 e assim por diante. Não se pode atribuir nota zero a nenhuma amostra.

O princípio da estimação de magnitude, ou função de potência, proporciona a obtenção de diversas ferramentas importantes para avaliação de alimentos pela análise sensorial. Os valores obtidos dos resultados dos julgadores e os valores das concentrações avaliadas são normalizados, calculados os logaritmos desses resultados e colocados em um gráfico em coordenadas logarítmicas. Para cada adoçante (ou outro composto) é obtida uma reta, a qual obedece à lei de Stevens, ou "Power function": S=aCn, onde S é o estímulo percebido, C é a concentração do estímulo, a é antilog do valor de Y no intercepto, e n é o coeficiente angular da reta. Regiões das retas dos adoçantes em que estão em mesmo nível, paralelo ao eixo da abscissa, possuem poder edulcorante equivalentes (MOSKOWITZ, 1970).

2.4 Testes Sensoriais Temporais

Dentre os testes sensoriais temporiais destacan-se o teste de dominância temporal das sensações e o teste de tempo intensidade.

2.4.1 Dominância Temporal de Sensações

A técnica do domínio temporal de sensações (TDS) é uma metodologia recente que permite gravar vários atributos sensoriais simultaneamente ao longo do tempo, e permite a obtenção de sequências de sensações (PINEAU et al., 2009; RÉVÉREND et al., 2008). Com este método descritivo sensorial, os julgadores avaliam qual a sensação é dominante e marcam sua intensidade ao longo do tempo até que a sensação termina ou outra aparece como dominante (LABBE et al., 2009). Segundo Albert et al. (2012), esta técnica permite o impacto que cada aspecto da percepção tem sobre o consumidor sobre o momento do consumo, e os resultados a serem ligados à aceitação.

2.4.2 Tempo Intensidade

A aplicação da análise de tempo intensidade está se tornando muito importante como uma forma de avaliar o alimento (MONTEIRO, 2002) por meio da associação da percepção humana, juntamente com os recursos de ciência da informação, permitindo a avaliação das informações obtidas sobre qualquer característica preestabelecida da amostra (BOLINI, 2003). Por meio desta técnica é obtida uma curva que grava a variação na intensidade de estímulo sensorial, percebida pelo membro do painel com a passagem do tempo.

Atualmente, esta técnica baseia-se na utilização de programas de computador para o tempo de intensidade (TI), a recolha e tratamento de dados, que tem uma interface, na forma de uma escala em que os membros do painel indicam a intensidade do estímulo ser recolhidos usando o *mouse* do computador. Estes programas permitem que a escolha do comprimento de escala para ser utilizada em cada ensaio e armazena a sequência de dados para utilização futura (NUNES, 2012). De acordo com Cliff e Heymann (1993) os parâmetros da curva de TI usados são: intensidade máxima (Imax), tempo para atingir a intensidade máxima (Timax) e o tempo total de duração do estímulo (Ttot). No entanto, com o avanço da tecnologia de computadores, outros parâmetros da curva podem ser facilmente obtidos, tais como a área sob a curva (Área), duração máxima intensidade (planalto), e o momento em que a intensidade máxima começa a declinar (DT) são frequentemente utilizados (NUNES, 2012).

Nos últimos anos, muitos estudos têm sido desenvolvidos a fim de quantificar as propriedades temporais de sais como o gosto amargo (KILCAST; RIDDER, 2007).

3 CONSIDERAÇÕES FINAIS

Observou-se neste estudo que os substitutos de cloreto de sódio (fosfato de potássio e lactato de potássio) possuem grande rejeição devido ao seu sabor desagradável. Os substitutos com maior aceitação foram o cloreto de potássio e o glutamato monossódico. A concentração ideal de sal no veículo (sopa de batata) foi de 0,9%. Cloreto de potássio e glutamato monossódico, deve ser adicionado ao caldo de batata, em concentrações de 1, 2146% e 4, 4314%, respectivamente. A combinação de cloreto de sódio com cloreto de potássio e glutamato monossódico possui uma boa aceitação sensorial até a substituição de 75% de cloreto de sódio. Este estudo serve de base para posteriores estudos sobre a redução de sódio em alimentos além de mostrar o grande potencial de desenvolvimento de produtos com redução de sódio.

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SEGUNDA PARTE – ARTIGOS

ARTICLE 1 Determination of ideal and salt equivalence of nacl substitutes

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DETERMINATION OF IDEAL AND SALT EQUIVALENCE OF NACL SUBSTITUTES

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ABSTRACT

Due to the problem of high sodium intake nowadays come back up efforts to develop products with low sodium content it is necessary to know the optimal concentration of each salt substitute and its equivalence with respect to sodium chloride is very important for one successful replacement. In this study, was evaluated the optimal concentration of sodium chloride in the potato soup and the equivalent magnitude of different salts with respect to sodium chloride. The optimal concentration of sodium chloride was determined using the ideal scale. Next, was determined the salt equivalent compared to sodium chloride (considered to be ideal in terms of salt) for each substitute studied and evaluated its salting through the magnitude estimation method. The concentration of sodium chloride considered ideal in potato soup was 0.9%. Using the magnitude estimation method, it was determined that to promote a salt equivalent to the ideal (0.9% sodium chloride) salt, potassium chloride and monosodium glutamate, should be added to potato soup at concentrations of 1.2146% and 4.4314%, respectively.

PRACTICAL APPLICATIONS

The purpose of this work is to study the use of NaCl substitutes and salt equivalence, including potassium chloride and monosodium glutamate. The study of NaCl substitutes is important because currently consumers demand for more healthy products and the fact of not having many studies related to these substitutes. Therefore, this work will give allowance for future studies, supports the development of a new product, attending consumer desires, and contributing to the variety of product in market.

Keywords: magnitude estimation method, potassium chloride, monosodium glutamate

1. INTRODUCTION

Sodium chloride (NaCl) is one of the most used ingredients for many foods. It has influence technological, sensory, and its preservative effect against microorganisms. Salt not only confers its own specific flavor on products, it is also used to enhance and modify the flavor of other ingredients, and to reduce the sensation of bitterness in some products. The precise flavor effect of salt is very product-specific, as the overall flavor of any particular product is affected by both the chemical and physical nature of its ingredients and their texture, and the relative levels of ingredients used. In addition the salt has been used as a preservative for thousands of years. The main preservative mechanism is via a reduction in water activity. Microorganisms require water to survive and grow. Salt in solution binds to some of the water, leaving a reduced level for the microorganisms (Hutton 2002).

However, NaCl has also been reported to increase the risk of hypertension and to be directly related to the development of cardiovascular disease (Souza 2013; Weinsier 1976; Law 1997). Therefore, the World Health Organization (WHO 1990) recommended a limitation of the average NaCl intake to 6 g per day for adults. Seventeen years later, WHO repeated this earlier warning and recommended an even lower daily sodium intake of 5 g per day (WHO 2007). Consequently, the reduction of NaCl content in food products has become an important challenge for the food industry. The more so, since a decrease in NaCl content is very often reported to be associated with a decrease in consumer acceptance (Sofos 1983; Breslin and Beauchamp 1997).

There are approaches to reducing NaCl content as to replace NaCl with other types of salts, such as potassium chloride (KCl) and calcium chloride ($CaCl_2$) (Kremer 2009). To reduce the sodium content in foods processed, previously studies for the understanding of ideal salt content should be conducted. Know the optimal concentration of each salt substitute and its equivalence with respect to sodium chloride is very important for successful replacement.

In the quest for the ideal product, different approaches may be used, such as overall liking rating by a consumer panel, ideal attribute rating by Just About Right (JAR) methodology, and overall typicality assessment by a panel of product experts (Ballester *et al.* 2005; Trijp *et al.* 2007). Just-about-right (JAR) scales have been used increasingly to identify attributes that need improvement and to determine the optimum level for an attribute in a product (Chambers and Wolf 1996). The Just About Right methodology is a direct approach to the measurement of the deviation from ideal levels per attribute. With JAR, assessors directly assess deviations from ideal, usually in terms of labeled scales with the end points "much too weak" to "much too strong", with the midpoint of the scale labeled as "just about right". This is a direct measure of the perceived attribute intensities, but it does not directly quantify them. This implies that the ideal attribute value is equal to or close to the most liked attribute value. JAR is usually expressed as the percentage of respondents who consider the attribute level as too high, too low, and just about right (Chambers 1996). Several studies have attempted to find optimal levels of sweetness and saltiness for various food systems using either JAR scales (McBride 1982; Johnson and Vickers 1987; Vickers 1988).

For the development of products with reduced sodium content is necessary to conduct studies to determine the appropriate concentration that must be added to the product to promote curing the same sodium chloride. The sensory acceptance in replacement of a salt can be improved using the technique of estimating the magnitude. Magnitude estimation, a ratio-scaling technique, is frequently employed to generate dose-response functions of sweeteners (Stevens 1969; Stone and Oliver 1969; Moskowitz 1970; Moskowitz 197l; Bartoshuk, 1975; Schiffman *et al.* 1981). This is an estimation of the magnitude and a graphic representation of standardized results through the Law of Stevens, or the "Power Function" (Souza *et al.* 2011).

There is little knowledge about the magnitude of equivalent salt substitutes, so the aim of this study was to evaluate the optimal concentration of sodium chloride and magnitude of equivalent salts sodium chloride and potassium chloride, monosodium glutamate. This was a basic study that will give allowance for future studies. For this study was chosen as vehicle the potato soup to be little influence on the perception of salt.

2. MATERIALS AND METHODS

Materials

The following is a list of materials used in the food preparations in this study: potato, water, potassium chloride – 99% (Vetec®), monosodium glutamate – 99% (Aji-no-moto®), and sodium chloride– 99% (Vetec®).

Preparation of Vehicle (potato soup)

For the preparation of potato soup, the potatoes were washed, peeled, chopped into cubes of approximately 3 cm edge. The potatoes were cooked with water at a ratio of 1:2 for 30 minutes in boiling water (96^{o}C). Once cooked, the potatoes were processed in a blender on high speed. Each salt was added as the treatment to be studied.

Sensory Analysis

Sensory evaluations were conducted at various stages to reach the equivalent salting for the various salts in relation to the salt of sodium chloride.

Determination of Ideal NaCl Concentration.

Determining the optimal concentration of NaCl (%) to be added to the potato soup was performed by means of an affective test, using the just-about-right scale (*Meilgaard et al.* 1999).

Five formulations of potato soup were prepared containing 0.5%, 1.0%, 1.5%, 2.0% and 2.5% sodium chloride. The definition of the central point of sodium chloride was defined on pre-tests.

The samples were served to panelists in individual booths in the Sensory Analysis Lab, Department of Food Science of Federal University of Lavras in a balanced complete blocks paradigm (Macfie *et al.* 1989). Sample's presentation was monadic in codified white disposable cups coded with three digit numbers. The presentation was made in monadic order in disposable white plastic cups coded with three-digit numbers. The panelists used the just-about-right scale anchored at the following extremes: extremely less salty than ideal (1) and extremely more salty than ideal (5), with the ideal salty corresponding to the value 3 (three). A total of 50 panelists were used who were consumers of potato soup. The panelists were college students aged between 18 and 25 years; 75% were female and 25% were male.

The sensory evaluation results were analyzed by an analysis of variance to make sure that there was no significant difference between samples, and an analysis of linear regression between the scores and sodium chloride concentrations, as suggested by Vickers (1988).

Selection of Panelists.

The selection was made using the sequential method proposed by Wald (Amerine *et al*. 1965), in which triangular tests are used to select subjects with a good ability to discriminate samples.

For the definition of samples that would be used in the triangular test and in Wald's sequential analysis for panelist selection, a paired comparison test was first performed.

Were recruited 50 consumers of salt who were interested in determining the equivalent salt in vehicle compared to sodium chloride and had available time and no restrictions as to the consumption of this product (Souza *et al.* 2011).

The sequential method proposed by Wald (Amerine *et al.* 1965) - where a number of tests triangular are applied was used to select panelist with a good ability to discriminate samples (Meilgaard *et al.* 1999).

In the triangular tests were used two samples of potato soup with 1% of significance difference. The samples were: potato soup with 1.0% of sodium chloride and butter with 1.25% of sodium chloride. From the defined parameters (p=0.30, p1=0.70, α = 0.10 and β = 0.10) the Wald graph was construct and judges were selected or rejected according to the number of correct tests analyzed in the triangular graph (Souza et al. 2011).

With 8 triangular tests, 14 judges were selected. The selected panelists were college students aged between 18 and 27 years and included 8 females and 6 males.

Training of Tasters to Use the Magnitude Scale.

The panelists selected were trained to use magnitude scales according to Souza et al. (2011). In the training session the panelists received three samples of potato soup (0.5%, 1% and 2% sodium chloride), and were asked to determine the potency of this samples with respect to a reference sample (potato soup with 1% sodium chloride). The ideal concentration of 1% sodium chloride was determined based on pretests.

Determination of the Equivalent Salting.

The selected and trained panelists received a reference sample (potato soup with optimal concentration of sodium chloride that was determined previously) with a potency designated by an arbitrary salting value of 1, followed by several potato soup samples coded and balanced (Macfie *et al.* 1989) with potencies higher than or lower than the reference. The panelists were asked to estimate the intensities of the salting of potato soup samples compared to the reference. For example, if the sample produced twice the salting of the reference, it should receive a value of 2; if it presented half the salting, it was given a value of 0.5.

To determine the equivalent saltiness of salts relative to sodium chloride, the series of concentrations presented in Table 1 were used. The central concentrations of the sodium chloride substitutes were based on pretests. To calculate the other concentrations, a multiplication factor of 1.6 was used, following Cardoso *et al.* (2004) and Marcellini *et al.* (2005).

For data analysis, the estimated saltiness magnitude values of sodium chloride and salts were converted into geometric averages, and these values were set to a logarithmic scale. The curves of concentration versus sensory response for each salt corresponded to a power function ("Power Function") with the following characteristics: $S = a.C^n$, where S is the sensation perceived, C is the concentration of the stimulus, a is the antilog of the y value in the intercept and n is the slope obtained (Moskowitz 1970).

To calculate the equivalent concentration of each salt, the equation obtained for the potato soup with sodium chloride was used, and in place of C (salt concentration), the value of 0.9% was assigned, which is the ideal saltiness of sodium chloride. Thus, the value of S (sodium chloride saltiness perceived) was mathematically estimated. The S values for sodium chloride were substituted into the other equations (for the other salts) and thus determined the optimal concentration of each salt in reference to the equivalent salt in potato soup with 0.9% sodium chloride (Souza *et al.* 2011).

TABLE 1. The concentrations of sodium chloride and each sodium chloride substitute used to determine the equivalent saltiness compared with potato soup with 0.9% sodium chloride.

Salts	**Concentration (%)**				
Sodium chloride	0.3516	0.5625	0.9000	1.4400	2.3040
Potassium chloride	0.5044	0.8070	1.2912	2.0660	3.3056

Monosodium glutamate	1.5074	2.4118	3.8589	6.1742	9.8787

Determination of the Salting Potencies

The strength of each salt was defined as the number of times that the compound is more salty than sodium chloride based on its equivalent salt to sodium chloride. That is, the power of the salt was calculated by the ratio between the optimal concentration of sodium chloride (0.9%) and the equivalent concentration of salt in the equivalent potato soup with 0.9% sodium chloride

3. RESULTS AND DISCUSSION

Determination of the Optimal Concentration of NaCl

According to the evaluation of consumers, a significant difference at a 1% probability by an F-test can be observed between the salted samples with different concentrations of sodium chloride. Therefore, a regression model was adjusted to relate the ideal salty with sodium chloride concentrations of processed samples potato soup. The linear model showed the best data fit (coefficient of determination of 0.948; Fig. 1). Through the regression equation, the amount of sodium chloride to be added to the potato soup was calculated and was found to be 0.9%.

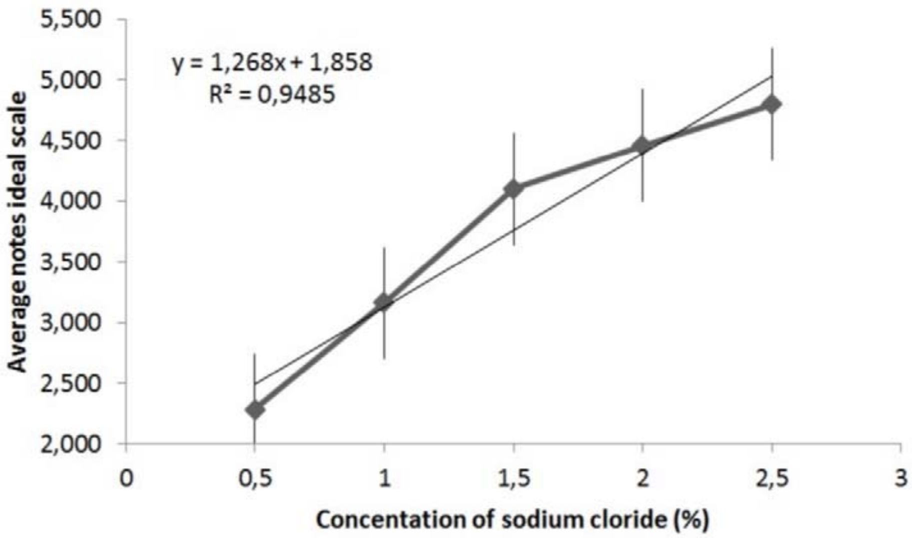

FIG. 1. Graphic representation of the regression equation and coefficient of determination of the average notes on the ideal scale as a function of the sodium chloride concentration in potato soup.

Equivalent saltiness

After obtaining the test data with the magnitude scale, the logarithmic values of concentrations (C) for sodium chloride and for each salty were plotted against the logarithmic values of the estimated magnitudes (appropriately normalized) for stimuli perceived as sensations (S). A linear regression of points obtained for sodium chloride and for the various salty was then made, and a straight line equation was obtained for each of the salty (Fig. 2). Using the position of the curves observed in the graph shown in Fig. 2, it is possible to identify the ratio of the salty of various salts used.

The sodium chloride curve precedes the curves of potassium chloride and monosodium glutamate, respectively (Fig. 2). This shows that sodium chloride has a higher salting sensation compared to other salts. The monosodium glutamate curve is distant from the others, indicating that for the same salting sensation, much higher concentrations of monosodium glutamate are needed.

From the equation for sodium chloride and each salt (Fig. 2), a simple power function was obtained: $S = a.C^n$ (Table 2). From the power functions obtained for sodium chloride and for each salt, the equivalent amount of salt necessary to provide the same salting as 0.9% sodium chloride was calculated (Table 3) It can be observed in Table 3 that sodium chloride required the larger quantity to promote the equivalent salting of 0.9% sodium chloride in potato soup.

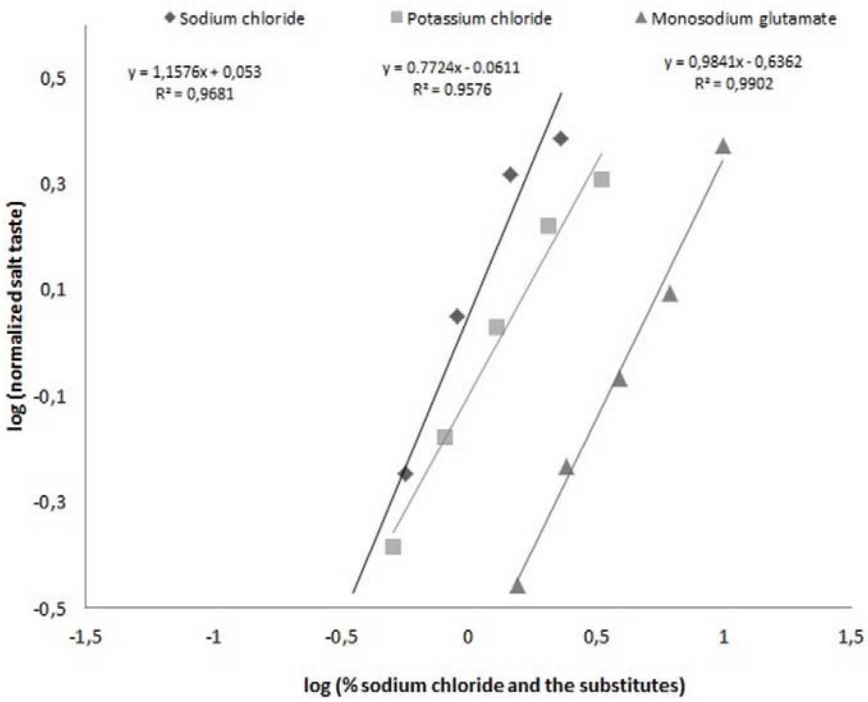

FIG. 2. Results of the linearized power function for potato soup salted with sodium chloride, potassium chloride and monosodium glutamate. The X-axis is the logarithmic concentration of the salts (%), and the y-axis is the logarithmic values of the estimated magnitudes after appropriate normalization.

The salty perception of sodium chloride is attributed to the cation (70–85%) and to the anion (30-15%) (Formaker and Hill 1988; Mattes 2001) and involves the passage of the ions through a narrow ionic channel. According Mccaughy (2007), this passage through these channels is a specificity of the ions of sodium chloride, being difficult to find other substances with this capability, except toxic ions. Thus, the salting capacity o depends on the type of cation/anion present in the substance (Ye *et al.* 1991; Ye *et al.* 1993). Compared with sodium chloride, other cations (potassium, magnesium and calcium) and other anions (phosphates and citrates) may have off taste and have less salty perception (Mooster 1980).

TABLE 2. Antilog of the y-intercept (a), intercept on the ordinate (n), linear coefficient of determination (R^2) and power function (Power Function) of the results to determine the equivalent saltiness of sodium chloride, potassium chloride and monosodium glutamate relative to the 0,9% sodium chloride in potato soup.

Salts	**a**	**n**	**R^2**	**Power Function**
Sodium chloride	1.1298	1.1576	0.9680	$S=1.1298C^{1.1576}$
Potassium chloride	0.8687	0.7724	0.9576	$S=0,8687C^{0.7724}$
Monosodium glutamate	0.2311	0.9840	0.9900	$S=0.2311C^{0.9840}$

In-depth studies were not found in the literature on the potency of the sodium chloride substitutes used in potato soup, so there is little information regarding their behavior in the complex matrix of a food.

Determination of the Salting Potency

Based on the values of equivalent concentrations presented, we calculated the strength of each salty and their combinations (Table 3).

Souza *et al.* (2013) determined, using the magnitude estimation method, that the potencies of potassium chloride and monosodium glutamate relative to the 1% sodium chloride in butter are 83.33 and 31.59, respectively. It can be observed that the salting potency varies with the type of product and according to the concentration of sodium chloride to be replaced.

TABLE 3. Equivalent concentrations and potencies of potassium chloride and monosodium glutamate relative to the 0.9% sodium chloride in potato soup.

Salts	**Concentration**	**Potency**
Potassium chloride	1.2146	82.33
Monosodium glutamate	4.4314	22.57

4. CONCLUSION

The concentration of sodium chloride considered ideal in potato soup was 0.9%. Using the magnitude estimation method, it was determined that to promote a salt equivalent to the ideal (0.9% sodium chloride) salt, potassium chloride or monosodium glutamate, should be added to vehicle at concentrations of 1.2146% and 4.4314%, respectively.

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ARTIGO 2 Optimization of a reduced sodium mix using multivariate analysis: mixture design and plackett-burman design

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ABSTRACT

Efficient product development techniques are used to get a new product in a short time. Optimization methods are useful within sensory science as a way to obtain a result under a specific set of conditions this to understand questions to provide potential formulas. In this work, response surface methodology was used for optimization of acceptance parameters in a reduced sodium mix using a mixture design and Plackett–Burman factorial designs. Sodium chloride and its substitutes potassium chloride, monosodium glutamate, potassium phosphate and potassium lactate proportions in a formulation of salt were optimized for consumer acceptance parameters. Through the Plackett-Burman designs substitutes for sodium chloride, potassium phosphate and potassium lactate were eliminated by the experiment have high rejection due to its unpleasant taste. An optimized salt was suggested with 25% of sodium chloride, 10% of potassium chloride and 65% of monosodium glutamate.

PRACTICAL APPLICATIONS

Plackett-Burman design was used in order to select relevant variables for a response surface methodology optimization of acceptance parameters in a development of a mixtures with sodium chloride reduction. The study of sodium chloride reduction is important because currently consumers demand for more healthy products and the fact of not having many studies related to these mixtures.

Keywords: optimization, salty, mixture design, Plackett-Burman

1. INTRODUTION

Much attention has focused on developing products with reduced sodium in view of the correlation between the intake of the mineral and the excessive increase of cardiovascular diseases. There is an Increasing number of studies in this area (Campagnol *et al.* 2012; Campagnol *et al.* 2011; Horita *et al.* 2011; Grummer *et al.* 2013; Karimi *et al.* 2012; Ayyash *et al.* 2012; Kamleh *et al.* 2012; Ayyash *et al.* 2011a, 2011b; Van Dender *et al.* 2010; Cerníková *et al.* 2010).

Efficient product development techniques are used to get a new product in a short time (Souza 2012; Ekpong *et al.* 2006). “Product optimization” stands for the disciplined approach to product development (Moskowitz 1994). Optimization methods are useful within sensory science as a way to obtain a result under a specific set of conditions (Kumar *et al.* 2010). This may be implemented to understand cause-and effect questions for ingredients or to provide potential formulas and direction for product development (Dooley *et al.* 2012). The ultimate goal of food product optimization is to maximize “consumer acceptance” of a product, thus defining a fixed set of ingredients (Lagrange and Norback 1987), and a number of methods have been developed to address it (Plaehn 2009; Dooley *et al.* 2012).

The Plackett–Burman factorial designs allow for the screening of main factors from a large number of process variables, and these designs are thus quite useful in preliminary studies in which the principal objective is to select variables that can be fixed or eliminated in further optimization processes as mixture design experiment.

Mixture design experiments are a very powerful tool to quantify different factors’ effect on production processes, and ultimately to determine which combinations of factors and levels provide optimal output quality (De Ketelaere *et al*. 2011). Mixture design methodology can be utilized for the optimization and investigation of the functions of processed foods' ingredients, and supports the importance of ingredient interactions (Abdullah and Cheng 2001; Siefarth *et al*. 2011; Dooley *et al*. 2012). Mixture design experiments are suitable for the study of products that involve more than one ingredient, as the levels and proportions of the components in the mixture are dependent on each other, and the sum of all components is always 1 or 100% (Hare 1974; Cornell 1983; Iop *et al*. 1999; Dutcosky *et al*. 2006; Dooley *et al*. 2012). This technique allows one to obtain a predictive mathematical representation of the relationship between mixture factors and responses (Cornell 1983; Neto *et al*. 2003).

Mixture design experiments were commonly analyzed by response surface methodology (RSM), which is one of the most widely used optimization techniques due to its efficiency and simplicity (Monaco *et al*. 2010). RSM can be used to optimize a product formulation and process conditions (Dean and Voss 1999; Chu and Resurreccion 2004, 2005; Meullenet *et al*. 2007; Shih *et al*. 2009). This is done by optimizing a response (dependent variable or output variable) by adjusting the levels of independent variables (input variables) which are measurable, controllable and continuous. Relationships between the variables may also be understood (Wai *et al*. 2009).

Mixture design and RSM have been extensively and successfully applied by several authors to determine the optimum formulation for a food product while evaluating sensory or physicochemical attributes (Acosta *et al*. 2008; Deshpande *et al*. 2008; Marchi *et al*. 2009; Felberg *et al*. 2010; Granato *et al*. 2010; Monaco *et al*. 2010; Mondragón-Bernal *et al*. 2010; Soukoulis and Tzia 2010; Karaman *et al*. 2011; Arcia *et al*. 2011; Dooley *et al*. 2012; Nikzade *et al*. 2012; Youn and Chung 2012).

The work aimed to use multivariate techniques, such as RSM (traditional modeling) in conjunction with RSM to optimize sensory parameters of a mixture of salt using a mixture design and Plackett–Burman factorial designs. These techniques were used to optimize five variables, sodium chloride and its substitutes potassium chloride, monosodium glutamate, potassium phosphate and potassium lactate, in formulation of a mixture of salt through sensory evaluations.

2. MATERIALS AND METHODS

Selection of Salts

Materials

The following is a list of materials used in the food preparations in this study: potato, water, potassium chloride – 99% (Vetec®), monosodium glutamate – 99% (Aji-no-moto®), potassium phosphate – 99% (CRQ®), potassium lactate– 99% (Purac®), and sodium chloride – 99% (Vetec®).

Obtention of Vehicle (potato soup)

For the preparation of potato soup, the potatoes were washed, peeled, chopped into cubes of approximately 3 cm edge. The potatoes were cooked with water at a ratio of 1:2 for 30 minutes in boiling water (96^{o}C). Once cooked, the potatoes were processed in a blender on high speed. Each salt was added as the treatment to be studied.

Sensory Analysis

Sensory analysis was performed in the laboratory of Sensory Analysis, Food Science Department, Federal University of Lavras (UFLA). An acceptance test was conducted on the attributes of taste and the global aspect using a hedonic scale of 9 points (1 = dislike extremely 9 = like extremely) (Souza et. al. 2013).

The test was conducted on 55 participants (36 women and 19 men), among them students and office staff aged between 18 and 40 years. Panelists were selected based on their regular consumption of potato. In the first sensory evaluation, each panelist evaluated 10 formulations in five sessions spread over five consecutive days. Two formulations were evaluated to each session.

Samples (table 1) of approximately 20 mL of potato soup were served in cups of 50 mL at temperature (55 - 60°C) in a balanced manner (Wakeling and MacFie, 1995). These were coded with three-digit numbers drawn from a table of random numbers. The test was conducted in individual booths under white light, with adequate ventilation. Tasters were offered enough water for the analysis. The laboratory temperature was set at 23°C.

For each set of samples, the panelists were instructed to taste and evaluate from left to right and rinse their mouths with water between samples. In addition, testers were instructed on the use of the hedonic scale.

Plackett-Burman Design

The 5 mixes tested are given in Table 1 along with their actual levels. The design used was Plackett–Burman design that comprised 5 factors spanning over 15 runs. As per the design, care was taken that all the ingredients appearing in any contribution have the same power salting. The equivalence of salting substitutes in relation to sodium chloride was established in pre-tests.

TABLE 1. Layout of the Plackett–Burman Experimental Design on Potato Soup

Mix	Sodium Chloride	Potassium Chloride	Monosodium Glutamate	Potassium Phosphate	Potassium Lactate
A	0,2250	0	0,5276	0	0
B	0,2250	0,5650	0	0,404	0
C	0	0,5650	0,5276	0	2,6320
D	0,2250	0	0,5276	0,4040	0
E	0,2250	0,5650	0	0,4040	2,6320
F	0,2250	0,5650	0,5276	0	2,6320
G	0	0,5650	0,5276	0,4040	0
H	0	0	0,5276	0,4040	2,6320
I	0	0	0	0,4040	2,6320
J	0,2250	0	0	0	2,6320
K	0	0,5650	0	0	0
L	0	0	0	0	0
M	0,1125	0,2825	0,2638	0,202	1,316
N	0,1125	0,2825	0,2638	0,202	1,316

O	0,1125	0,2825	0,2638	0,202	1,316

Optimization of Mixtures

From the selected variables in the Plackett-Burman design a simplex lattice mixture design (Cornell 1983) was used. The design with the experimental levels for the five factors is presented in Table 2.

The proportion of Sodium Chloride, Potassium Chloride, and Monosodium Glutamate in the mixed salt was correlated against the consumer acceptance for taste and the overall liking by a first-order polynomial model. Internal preference mapping were performed according to Nunes et al. (2011).

All procedures were performed using the Chemoface program (Nunes *et al.* 2012) and Sensomaker program (Pinheiro *et al.* 2013).

TABLE 2. Compositions of Salt Mixture Samples in a Simplex Lattice Mixture Design

Mix	Sodium Chloride	Potassium Chloride	Monosodium Glutamate
1	0,9000	0	0
2	0	1,0932	0
3	0	0	3,9876
4	0,3000	0,7288	0
5	0,6000	0,3644	0
6	0,3000	0	2,6584
7	0,6000	0	1,3292
8	0	0,7288	1,3292
9	0	0,3644	2,6584
10	0,3000	0,3644	1,3292

RESULTS AND DISCUSSION

The selected variables in the Plackett-Burman design were sodium chloride and monosodium glutamate (p=0.05). Besides these was chosen potassium chloride by owning large industrial application.

Table 3 shows the models and the statistical parameters relating levels of the salt in the formulations to the acceptance for taste and overall liking. All models presented R^2 above 0.66 and significant ($P < 0.01$) regressions, indicating that they were suitable for the purpose of prediction (Henika 1982).

TABLE 3. Predicted Models for Sensory Data from Mixed Salt Samples

Attribute	Predicted model	R^2 value	P value
Taste	$Y = 6.7327X_1 + 3.5873X_2 + 5.4055X_3$	0.6623	<0.001
Overall liking	$Y = 6.8673X_1 + 4.0091X_2 + 5.5691X_3$	0.6618	<0.001

X1, sodium chloride; X2, potassium chloride; X3, monosodium glutamate.

Initially a numerical optimum for each acceptance attribute, as well as its factor levels, was found from several combinations among the levels of the five factors using the fitted polynomial model (Table 4). The optimum levels to the other factors were approximately 25% of sodium chloride, 10% of potassium chloride and 65% of monosodium glutamate.

TABLE 4. Numerical Optimum for the Acceptance and Respective Proportions of the Salts

Attributes	Proportions of the salt			Predicted acceptance
	Sodium chloride	Potassium chloride	Monosodium glutamate	
Taste	0.2250	0.1093	2.5919	6.53
Overall liking	0.4500	0.1093	1.5950	6.33

A contour plot for the taste (Fig. 2a) and overall liking (Fig. 2b) obtained by the fitted model was generated after being eliminated the variables less accepted, potassium lactate and potassium phosphate.

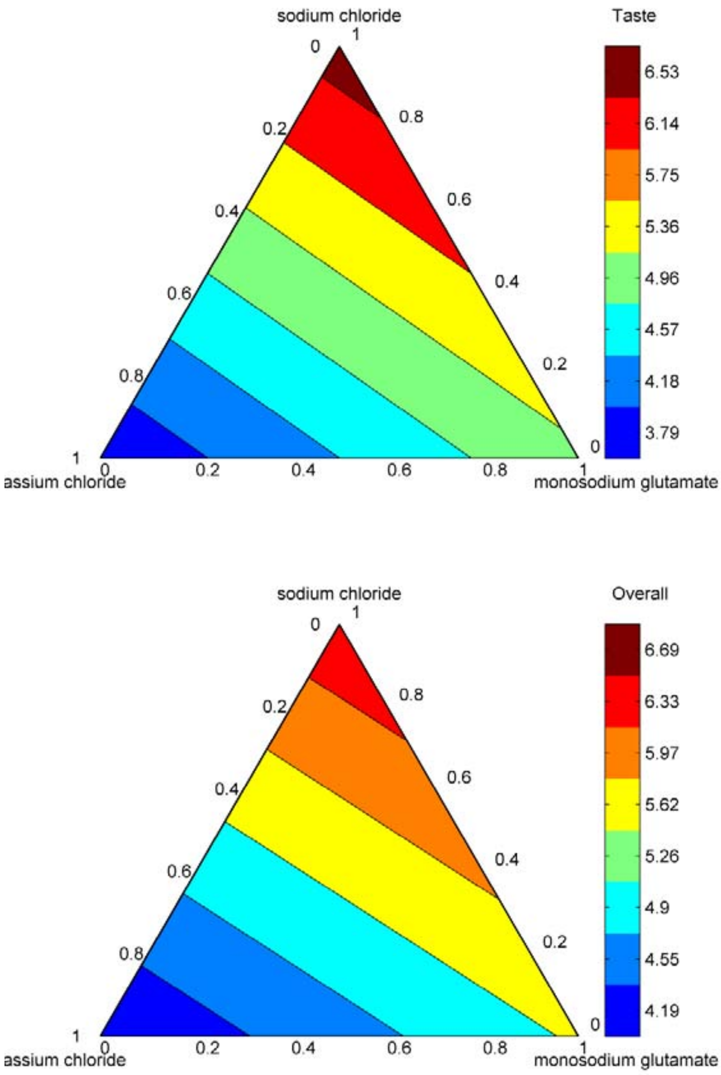

Figure 2 (a). Taste (b). Overall Liking. Contour curves for acceptance, with sodium chloride, potassium chloride and monosodium glutamate.

CONCLUSION

Multivariate optimization methods are an effective tool for the improvement of sensory characteristics during the development of new products. The best formulations were those with the following proportions of salt: 25% of sodium chloride, 10% of potassium chloride and 65% of monosodium glutamate.

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ARTICLE 3 **Sensory characterization of a reduced sodium mixture of salts**: time intensity and temporal dominance of sensations analysis

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ABSTRACT

The reduction of sodium in foods has garnered much attention once that studies indicate a positive correlation between dietary salt intake and some diseases. The objective of this study was to determine the flavor profile of many sodium chloride substitutes and mixtures with sodium chloride reduction and determine the time intensity of salty taste in these various salt mixtures using the analysis of Temporal Dominance of Sensations (TDS) and analysis of Time Intensity (TI). In the sensory profile of the tested salt substitutes, a bitter taste was perceived in the potato soup with potassium chloride and umami tastes were dominant in the potato soup with monosodium glutamate. The three mixtures tested were mixture 1 with 25, 10 and 65%, mixture 2 with 50, 10 and 40%, and mixture 3 with 75, 15 and 10% of sodium chloride, potassium chloride and monosodium glutamate, respectively. Mixtures with 75% sodium chloride showed higher Imax (5.3182) followed by mixing with 25% (4.5477) sodium chloride and 50% (3.9914) sodium chloride, respectively.

PRACTICAL APPLICATIONS

The purpose of this work is to study the the flavor profile of NaCl substitutes and mixtures with sodium chloride reduction, including potassium chloride and monosodium glutamate. The study of NaCl substitutes is important because currently consumers demand for more healthy products and the fact of not having many studies related to these substitutes and mixtures. Therefore, this work will give allowance for future studies, supports the development of a new product, attending consumer desires, and contributing to the variety of product in market.

Keywords: TDS, TI, potassium chloride, monosodium glutamate, potato soup.

INTRODUTION

The major source of sodium in our foods is the common salt or sodium chloride (He & MacGregor 2010). Sodium chloride is used in many foods because of its low cost and several important properties (Albarracín et al. 2011). Salt is commonly used to provide saltiness and to improve flavour although it also has other technological properties (Desmond 2006; Man 2007; Taormina 2010).

In the past few years, the reduction of sodium in foods has garnered much attention. The recent attention is in line with the drive by the World Health Organization who has called on food manufacturers to lower the sodium content in food products. The WHO recommends a daily salt intake of 5 g per day and this will require large reductions from current salt intake levels (WHO 2007).

Conclusive evidence for the effects of dietary sodium on blood pressure comes from a broad range of different studies, there is an increase in blood pressure that appears be attributable primarily to an increase in dietary sodium consumption (Souza et al. 2013; Busch et. al. 2013; Albarracín et al. 2011; Sacks et al. 2001; Scientific Advisory Committee on Nutrition 2003; Institute of Medicine 2004).

The development of low-salt products can be possible using different sodium chloride substitutes, such as other chloride salts (e.g., KCl) (Souza et al. 2013; Aliño et al. 2010), phosphates (Ruusunen & Poulanne 2005), transglutaminase (Romero de Ávila et al. 2010) or flavour enhancers such as monosodium glutamate (Desmond 2006).

Most of the research for reducing sodium intake from table salt has focused around salt substitutes with potassium. Potassium chloride is salty tasting and studies have indicated that an increased intake of dietary potassium can exert a protective effect in individuals with sodium-induced hypertension (Drake & Drake 2010; Lecos 1983; Linas 1991; Haddy 2006).

One problem with the use of potassium chloride as a salt substitute is a bitter aftertaste. Several studies have shown no sensory difference with regards to bitter taste when substituting 30–40% sodium chloride with potassium chloride, but when potassium chloride was substituted at a higher percentage, a bitter taste was noticed (Souza et al. 2013; Drake & Drake 2010; Rapacci et al. 1990; Aly 1995; Gou et al. 1996).

The sodium chloride substitutes may have unpleasant taste (Cruz et al. 2011), thus it is also important to know sensory characteristics of sodium chloride replacements to determine the salt substitute or blend that has a sensory profile more similar to NaCl (Souza et al. 2013).

Temporal dominance of sensations (TDS), proposed by Pineau et al. (2003), is a recent methodology that provides the sequence of sensory attributes perceived over time. Tasters assess which sensation is dominant over time until the sensation ends or another appears as dominant (Pineau et al. 2009; Labbe et al. 2009). According to Albert et al. (2012), the sensory profile obtained by this technique can be related to acceptance.

The time–intensity technique measures the sensory perception of the intensity of a specific attribute, and enables the monitoring of perceptual intensity changes during product evaluation (Lee & Pangborn 1986; Cliff & Heymann 1993; Desobry-Banon & Vickers 1998; Piggott 2000; Chung et al. 2003). According to Cadena and Bolini (2011) the time–intensity analysis has been widely used in studies to determine the behavior of sweeteners, in studies concerning beverages, chewing gum, meat product, salad dressing, olive oil, gelatins, dairy products and in the study of salts.

The objective of this study was to determine the flavor profile of many sodium chloride substitutes and mixtures with sodium chloride reduction and to determine the time intensity of salty taste in these various salt mixture.

MATERIALS AND METHODS

Materials

The following is a list of materials used in the food preparations in this study: potato, water, potassium chloride – 99% (Vetec®), monosodium glutamate – 99% (Aji-no-moto®), and sodium chloride – 99% (Vetec®).

Preparation of Formulations

The mixtures of the salts were prepared according to Table 1. The values were established by testing for pre-formulations were 25, 50 and 75% reduction in sodium chloride.

TABLE 1 Mixtures of sodium chloride and substitutes with 75% of reduction sodium chloride (mixture 1), 50% of reduction sodium chloride (mixture 1) and, 25% of reduction sodium chloride (mixture 1).

Mixture	Sodium Chloride (%)	Potassium Chloride (%)	Monosodium Glutamate (%)
1	0.2250	0.1093	2.5919
2	0.4500	0.1093	1.5950
3	0.6750	0.1639	0.3988

Preparation of Vehicle (potato soup)

For the preparation of potato soup, the potatoes were washed, peeled, chopped into cubes of approximately 3 cm edge. The potatoes were cooked with water at a ratio of 1:2 for 30 minutes in boiling water (96^{o}C). Once cooked, the potatoes were processed in a blender on high speed. Each salt was added as the treatment to be studied as Table 1.

Sensory Analysis

Sensory evaluations were conducted at various stages for the various salts in relation to the salt of sodium chloride.

Selection of Panelists

We recruited 10 participants (7 F and 3 M) to participate in the time intensity analysis and temporal dominance of sensations analysis as described by Souza *et. al.* (2013). Pre-tests were conducted to determine the salting equivalence and power of mixtures compared to pure sodium chloride.

Time Intensity Analysis (TI)

In three sessions, the ten panelists that were recruited from the panel of the salting equivalence test, were trained to familiarise themselves with the TI scale and varying salt intensities.

Panelists evaluated the salty taste of the potato soup by means of monadic presentation with three repetitions, using the mouse to record the perceived intensity of salty taste for 20 s. A rinse protocol between samples consisted of rinsing with water, a bit of unsalted cracker and rinsing with water again.

Panelists received 2 h of training to learn the time-intensity protocol. During this time, they received verbal instructions and practiced time-intensity scaling with salt solutions using the identified protocol, as described by Drake and Drake (2010). On the first signal given by the computer, the panelist took the full amount (around 5g) of the sample in the mouth and, using the mouse, indicated the intensity of the salty taste. On the second signal, the panelist expectorated the sample while a third signal indicated the end of the test.

Data collected during each sensory evaluation session included the following parameters: Imax (maximum intensity recorded by the judge); Time (time in which the maximum intensity was recorded); Area (area of time curve X intensity); and Ttot (total time of duration of stimulus). The collection of the data for the time-intensity analysis was carried out using the data acquisition program SensoMaker (Pinheiro *et al.*, 2013).

Temporal Dominance of Sensations (TDS)

Two preliminary sessions were conducted, as described by Albert *et al.* (2012). In the first session, the panelists were introduced to the notion of the temporality of sensations (TDS) and were introduced to the data acquisition program SensoMaker (Pinheiro *et al.*, 2013). In the second session, the panelists participated in a simulation of a TDS session with several samples of potato soup to answer any questions of the participants and so they could get used to the computer program and methodology. This session also defined the total duration time of the experiment to be 20 s, and the attributes selected by the panel were salty, bitter, sweet, umami, sour, spicy, astringent and off-taste

Finally, the panel evaluated three replicates of each of the six samples of potato soup: the standard potato soup sample with sodium chloride (0.9%) and two samples of potato soup with sodium chloride substitutes (potassium chloride and monosodium glutamate), at the concentration that promoted the same degree of saltiness as sodium chloride, 0.9%. The three mixtures tested were mixture 1 with 25, 10 and 65%, mixture 2 with 50, 10 and 40%, and mixture 3 with 75, 15 and 10% of sodium chloride, potassium chloride and monosodium glutamate, respectively.

The participants were requested to select the dominant taste over the time. To avoid possible misunderstandings, was clearly explained that the dominant taste is the taste that is perceived with greater clarity and intensity among others. Then, the panelists were requested to put the sample of potato soup (around 5g) in the mouth and immediately start the evaluation.

The samples were served one by one, and the assessors were asked to rinse their mouth with water between each sample. The presentation was made in monadic order (Macfie *et al*. 1989) in disposable white plastic cups coded with three-digit numbers.

The methodology of Pineau *et al*. (2009) was used in the software SensoMaker to compute the TDS curves. In brief, two lines are drawn in the TDS graphical display, the “chance level” and the “significance level”. The “chance level” is the dominance rate that an attribute can obtain by chance and the “significance level” is the minimum value this proportion should equal to be considered to be significantly (Pineau *et al.* 2009). It is calculated using the confidence interval of a binomial proportion based on a normal approximation, according Pineau *et al*. 2009 (1).

$$Ps = Po + 1.645\sqrt{\frac{Po(1-Po)}{n}} \qquad (1)$$

Ps: lowest significant proportion value (a = 0.05) at any point in time for a TDS curve; n: number of subjects *replication.

RESULTS AND DISCUSSION

Time Intensity Analysis (TI)

Time-intensity curves obtained from averages of 10 tasters better illustrate these results (Figure 1, 2, and 3). The mixtures 1 and 2 showed a very similar salty profile (Figure 1 and 2).

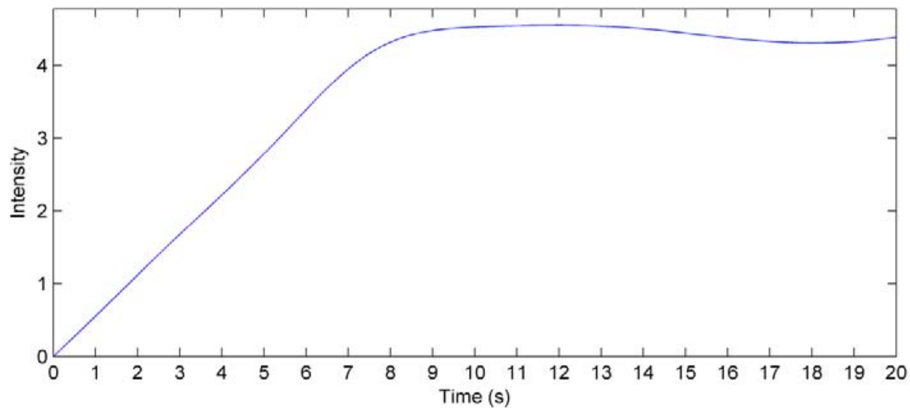

FIGURE 1 A graphical TI representation for the potato soup with mixture of sodium chloride (0.2250%), potassium chloride (0.1093%), and monosodium glutamate (2.5919%).

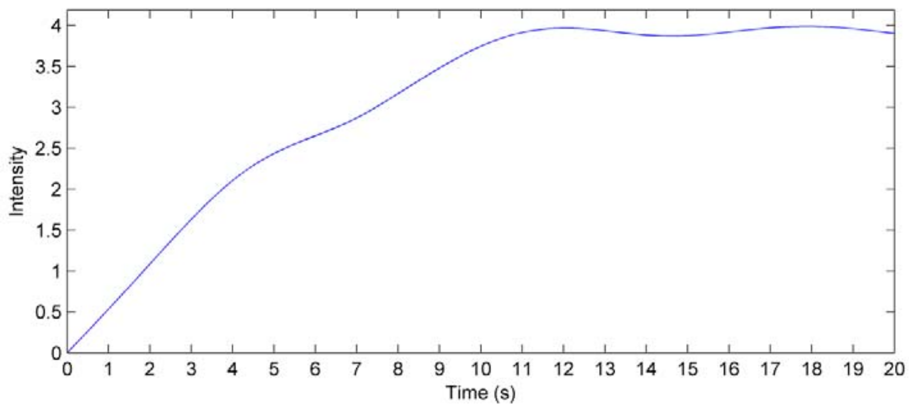

FIGURE 2 A graphical TI representation for the potato soup with mixture of sodium chloride (0.4500%), potassium chloride (0.1093%), and monosodium glutamate (1.5950%)

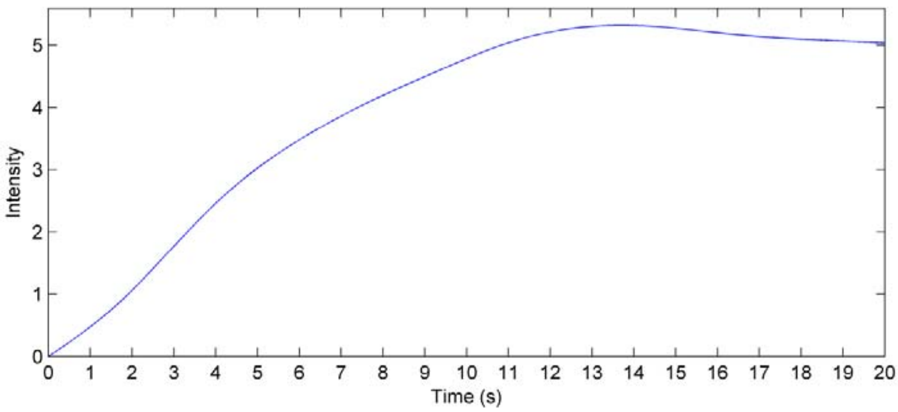

FIGURE 3 A graphical TI representation for the potato soup with mixture of sodium chloride (0.6750%), potassium chloride (0.1639%), and monosodium glutamate (0.3988%)

Time-intensity parameters varied among the salts (Table 2) at equivalent sodium potency, once again suggesting that other minerals play a role in salty taste. Salt mixture 3 reached higher salty taste intensities (5.3182, Imax) and the duration of salty taste lingered for a much longer time.

TABLE 2 Average of time-intensity curve parameters for salty taste.

Mix	Imax	TI 5% (s)	TD 5% (s)	TI 90% (s)	TD 90% (s)	Plateau 90% (s)	Area
1	4.5477 b	0.6000 a	20 a	7.4000 a	20	12.6000	71.1285b
2	3.9914 a	0.4000 b	20 a	9.4000 b	20	10.6000	61.150 a
3	5.3182 c	0.6000 c	20 a	10.200 c	20	9.8000	78.796 c

Means with common letters in the same column indicate that there is not a significant difference between samples ($p \leq 0.05$) from Tukey's mean test.

I_max: maximum intensity perceived

TI 5%: time when intensity is 5% of I_max at increasing part of the curve in seconds

TD 5%: time when intensity is 5% of I_max at decreasing part of the curve in seconds

TI 90%: time when intensity is 90% of I_max at increasing part of the curve in seconds

TD 90%: time when intensity is 90% of I_max at decreasing part of the curve in seconds

Plateau 90%: time interval which the intensity is ≥ 90% of I_max in seconds

Area: total area under the curve

Mix: (1) 25, 10 and 65%; (2) 50, 10 and 40%; (3) 75, 15 and 10% of sodium chloride, potassium chloride and monosodium glutamate, respectively.

Temporal Dominance of Sensations (TDS)

Figures 4, 5, and 6 show the TDS profiles for the three potato soups with only one salt and figures 7, 8, and 9 show the TDS profiles for the three potato soups with mixture of salt substitutes evaluated in the study. Each curve represents the change in the dominance rate of an attribute over time. The TDS analyses show that in the potato soup with sodium chloride (Figure 4), the salty taste was the dominant taste throughout the measured time. In the potato soup with potassium chloride (Figure 5), the salty taste and bitter taste are dominant, and salty was perceived with greater dominance rate than bitter up to approximately 12 s, but after that time, the bitter taste dominated.

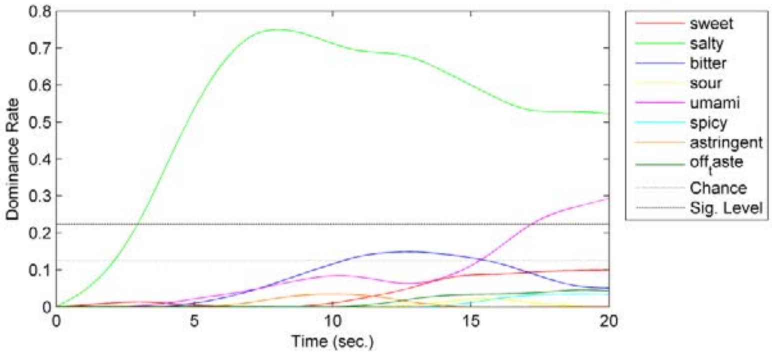

FIGURE 4 A graphical TDS representation for the potato soup with sodium chloride (0.9000%)

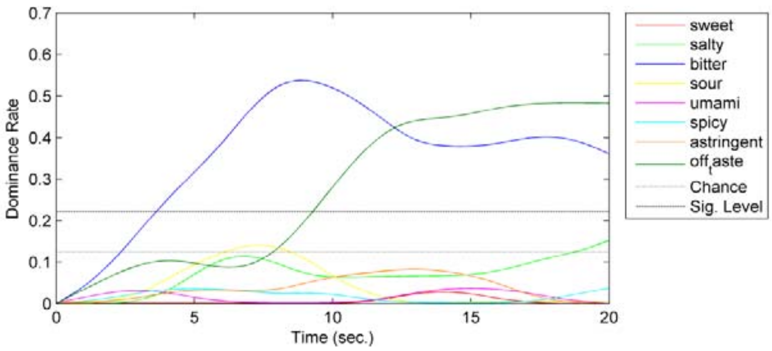

FIGURE 5 A graphical TDS representation for the potato soup with potassium chloride (1.0932%)

The salty perception of NaCl is attributed either to the cation (70–85%) and the anion (30-15%) (Formaker & Hill 1988; Mattes 2001), and according to Albarracín *et al*. (2011), cations and anions have an effect on the taste properties of different types of salt. Compared with sodium chloride, other cations (potassium, magnesium and calcium) and other anions (phosphates and citrates) interfere in the taste, resulting in a perception of unpleasant taste, as sourness and residual metallic taste (Mooster, 1980). According to Horita *et al*. (2011), potassium chloride is widely used in low-sodium products but in high concentration produces a bitter and metallic taste, resulting in sensory rejection (Seman *et al.* 1980; Askar *et al.* 1994; Guerrero *et al.* 2008; Armenteros *et al.* 2012).

In the potato soup with monosodium glutamate (Figure 6), the dominant tastes were salty and umami; and almost insignificantly off flavor were perceived. A similar number of participants evaluated salty and umami as dominant at the same time period. The salty taste dominated with high dominance rate until approximately 15 s. The umami taste had low intensities between approximately 14 and 18 s.

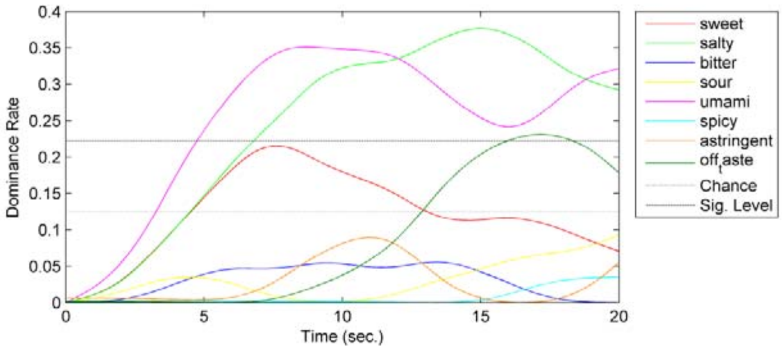

FIGURE 6 A graphical TDS representation for the potato soup with monosodium glutamate (3.9876%)

In potato soup with monosodium glutamate, there were no undesirable tastes (bitter, sour or off-taste). In this salt, the predominant tastes were umami and salty. Considering the dominant profile sensations of the salts studied, glutamate appears to have the greatest potential for use as a substitute for sodium chloride. According to Brandsma (2006) the flavor enhancers - compounds that activate the receptors in the mouth and throat - may be of great interest to the food industry, because it can help in the reduction of the levels of sodium chloride. However, considering that the glutamate salty power is well below the sodium chloride, the use of this sodium chloride substitute alone probably will not significantly reduce the level of sodium. Interestingly the glutamate is probably the largest anion that you examined and therefore unlikely to Enter 'narrow ionic channels' (Souza *et al*. 2013).

The formulation of potato soup with mixture of sodium chloride (0.2250%) and substitutes, potassium chloride (0.1093%) and monosodium glutamate (2.5919%) (Figure 7), the dominant tastes were salty and umami. The salty taste dominated with high dominance rate until approximately 7 s. The umami taste had intensity perceived between approximately 12 and 16 s.

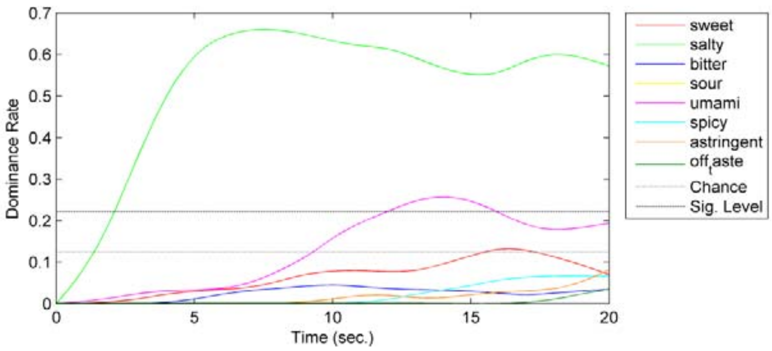

FIGURE 7 A graphical TDS representation for the potato soup with mixture of sodium chloride (0.2250%), potassium chloride (0.1093%), and monosodium glutamate (2.5919%)

In potato soup with mixture of sodium chloride (0.4500%) and substitutes, potassium chloride (0.1093%) and monosodium glutamate (1.5950%) (Figure 8), the dominant tastes were salty and almost insignificantly sweet and umami flavor were perceived. The salty taste dominated with high dominance rate until approximately 7 s.

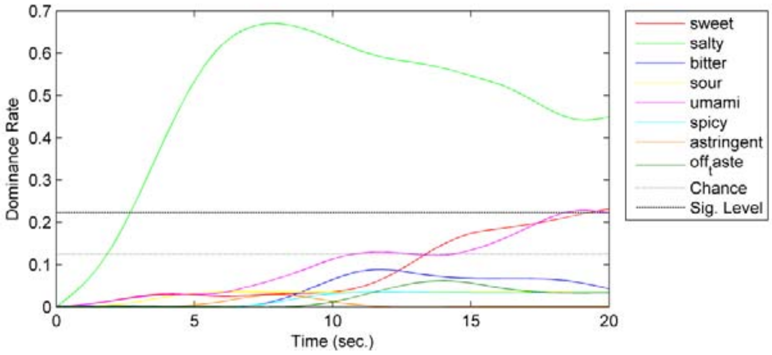

FIGURE 8 A graphical TDS representation for the potato soup with mixture of sodium chloride (0.4500%), potassium chloride (0.1093%), and monosodium glutamate (1.5950%)

The potato soup with mixture of sodium chloride (0.4500%) and substitutes, potassium chloride (0.1093%) and monosodium glutamate (1.5950%) (Figure 9), the dominant taste was salty was perceived. The salty taste dominated with high dominance rate until approximately 12 s. The salty taste had low intensities as from approximately 15 s.

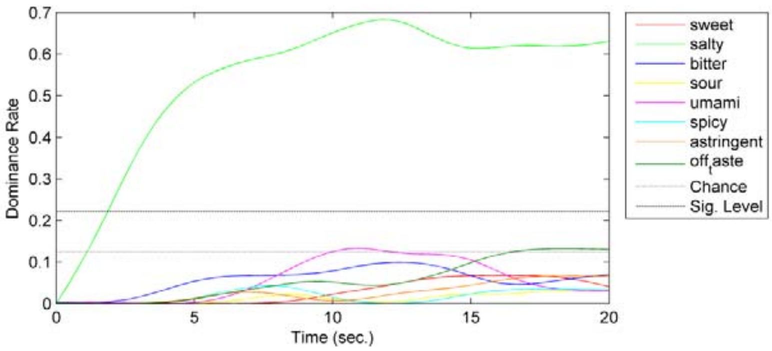

FIGURE 9 A graphical TDS representation for the potato soup with mixture of sodium chloride (0.6750%), potassium chloride (0.1639%), and monosodium glutamate (0.3988%)

The TDS curves also show that the potato soup with sodium chloride achieved a maximum dominance rate of 0.7 (the maximum of testers who selected saltiness as dominant was 70%) for saltiness, and the other sodium chloride substitutes reached a maximum saltiness dominance rate of 0.45. While the mixtures reached a maximum saltiness dominance rate of 0.68. The duration and the maximum dominance rate of the salty taste was greater in the potato soup with sodium chloride than for the other substitutes.

According to the results of TDS analysis, the total replacement of sodium chloride by potassium chloride or by monosodium glutamate in potato soup is not recommended, because these substitutes have undesirable tastes and/or low salty power in this product. However, in the mixtures of substitutes with sodium chloride, these undesirable tastes are insignificant.

It is important to emphasize that recent studies have been able to develop products with reduced sodium and good acceptability, but in all cases, the partial substitution of sodium chloride was used and even the replacement of sodium chloride with different blends of sodium (Souza *et al.* 2013; Katsiari *et al.* 2001; Guinee & O'Kennedy 2007; Reps *et al.* 2009; Horita *et al.* 2011; Mutamed *et al.* 2013, Cruz *et al.* 2012).

CONCLUSION

The sensory profile of the tested salt substitutes showed that a bitter taste was perceived in the potato soup with potassium chloride and sweet and umami tastes were dominant in the potato soup with monosodium glutamate. Mixtures with 75% sodium chloride showed higher Imax (5.3182), followed by mixing with 25% (4.5477) sodium chloride and 50% (3.9914) sodium chloride, respectively. It is possible to reduce the sodium chloride by 75% while maintaining good perception of salty taste intensity.

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