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**Increasing oil concentration affects consumer perception
and physical properties of mayonnaise-type spreads
containing KCl**

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Abstract

Reducing sodium intakes remains a global challenge for the food industry. KCl is a potential salt substitute but imparts bitterness when used at high concentrations. Little is known about how oil concentrations (OC) affect consumers' perception of saltiness and bitterness in emulsion products such as mayonnaise containing KCl. We evaluated consumers' perception and physical properties of mayonnaise-type spreads at various oil and tastant (NaCl or KCl) concentrations. Consumers (N=306) evaluated saltiness, bitterness, overall taste liking (OTL) and purchase intent (PI). Viscosity, pH, water activity and consistency/texture were also measured. Oil and tastant (NaCl or KCl) concentrations had significant effects on saltiness, viscosity, and pH. As OC increased, saltiness intensity slightly decreased for spreads. Increasing oil concentration increased viscosity. Generally, spreads containing KCl had higher bitterness and pH than spreads containing NaCl. All spreads containing KCl were penalized for being "too bitter". PI was affected by OTL for all spreads but OC was also a significant factor in the purchase decision of spreads containing NaCl. This study demonstrated that increasing OC affected consumers' taste perception (saltiness and bitterness) and spreads' physical properties including pH and viscosity.

Keywords: saltiness; bitterness; NaCl; KCl; oil-in-water emulsion.

Practical applications:

The strong association between excessive sodium consumption and hypertension and cardiovascular diseases is pressuring the food industry to find alternatives to replace sodium in foods. KCl, a salt substitute, may impart bitterness and metallic aftertaste. The composition of food matrices plays an

important role in consumer acceptability. This study evaluated consumer perception and physical properties of mayonnaise-type spreads at various oil and tastant (NaCl or KCl) concentrations. Increasing oil and tastant concentrations significantly affects perception and acceptability of spreads. This study can help the food industry to understand effects of oil concentrations on sensory properties of reduced-sodium emulsion products.

Introduction

Salt (NaCl), the most common food additive in the food industry, is used to provide salty taste and to improve flavor in foods. It is also used for food preservation, structuring and other important food applications (Kilcast and den Ridder 2007; Heshmati 2014). However, elevated sodium intake is associated with hypertension and cardiovascular diseases, which are the leading causes of deaths in the United States (Appel and others 2011; CDC 2016). Several approaches have been investigated to reduce sodium in human diets including stealth sodium reductions, saltiness potentiation, multisensory applications, and physical modifications of salt crystals (Kuo and Lee 2014). Use of salt substitutes (ingredients that taste salty but with no sodium) is an alternative for sodium reduction (Liem and others 2011) but it appears no other salt can match NaCl in terms of taste quality and acceptability. Saltiness of NaCl is unique, pure and clean as its cation and anion are associated with overall taste quality (Murphy and others 1981; Deman 1976). Potassium chloride (KCl) is a potential salt substitute; however, KCl has the drawback of imparting bitterness, metallic aftertaste, and off-taste (Hooge and Chambers 2010).

Modifying food matrix properties that affect sodium release and saltiness perception is another approach for reducing sodium (Kuo and Lee 2014; Busch and others 2013; Thurgood and Martini 2010). This includes the modification of viscosity, overall salt distribution, and pH (Busch and others 2013). Previous studies by our research group demonstrated that modifying physical properties of oil-in-water emulsions containing KCl significantly affected taste perception (Torrìco and others 2015a; Torrìco and others 2015b, Torrìco and others 2015c). These studies concluded that oil in

emulsion systems exhibited a bitterness-suppressing effect at recognition threshold levels (< 0.12 g/100 ml of KCl; Torrico and others 2015c), and a saltiness-enhancing effect at consumer consumption levels (0.5% to 1.5% of KCl; Torrico and others 2015a). However, food matrices are complex systems with several binary and tertiary interactions among basic tastes. In food-emulsion models, Shamil and others (1991-1992) stated that fat increased saltiness in salad creams, and decreased bitterness in Cheddar cheeses. Wendin and others (1999) reported that decreasing oil content in mayonnaise decreased sourness due to a water dilution effect of acetic acid. In a different study, Wendin and others (2000) demonstrated that increasing fat content enhanced saltiness of cream cheeses. Koriyama and others (2002) found that oil did not affect sweetness nor saltiness directly but decreased sourness and bitterness in emulsions. In terms of acceptability, Lin and others (1991) demonstrated that partial substitution of NaCl with KCl (18.3%) provided optimal sensory responses in restructured hams. KCl partial replacement of sodium produced significant increases in bitterness but did not affect flavor of bologna (Seman and others 1980). The acceptability level of KCl replacements or substitutions is dependent on the composition of the food matrix system (Hooge and Chambers 2010).

There are few studies attempting to understand the effects of oil on taste perception in food emulsion systems containing KCl. Thus, the objective of this research was to evaluate consumer perception and physical properties of mayonnaise-type spreads at various oil and tastant concentrations to unveil main sensory and physical differences of NaCl and KCl in oil-in-water emulsion systems.

Materials and Methods

Preparation of mayonnaise-type spreads

Mayonnaise-type spreads were similarly prepared to the procedure described in Garcia and others (2009). Canola oil (CWP, Cal Western Packaging Corp., Memphis, Tenn., U.S.A.) and Ozarka®

spring water (Nestle Waters North America, Greenwich, Conn., U.S.A.) were used as the base formulation for all emulsions. Tic Pretested® Ticaloid® 210S powder (gum acacia and xanthan gum; Tic Gums®, Inc., White Marsh, Md., U.S.A.) was used as a stabilizer, whey protein isolate (Grande Ultra®, Grande Custom Ingredients Group, Lomira, Wis., U.S.A.) was used as gelation and thickening agent, vinegar (Great Value™, Walmart, Ark., U.S.A.) was used as an acidifier, and sodium chloride (NaCl, Morton Intl., Inc., Chicago, Ill, U.S.A.) or potassium chloride (KCl, 99% FCC grade, Extracts and Ingredients, Ltd., Union, N.J., U.S.A.) were used as main tastants. For preparing the spreads, ingredients were first weighed out using an analytical balance (MS105, Mettler-Toledo, L.C.C., Columbus, Ohio, U.S.A.) according to the formulations described in Table 1. NaCl or KCl, Tic gum, whey protein isolate and vinegar were thoroughly dissolved in water and mixed with canola oil for 15 min using a hand-held blender at high-speed (Model #59780R, Hamilton Beach® Brands Canada, Inc., Picton, Ont., Canada). After forming the emulsion, each spread sample was poured into 500 mL plastic containers and kept at refrigerated temperature (4 °C) prior to testing. Before serving, 30 mL of spread sample was poured into a plastic cup with a lid that was previously coded with 3-digit random numbers. Differences in concentrations of NaCl and KCl (Table 1) for the experimental design were pre-determined according to their relative saltiness intensities described in Torrico and others (2015b).

Physical properties of mayonnaise-type spreads

Viscosity of each spread sample was measured in centipoise (cP) at 20±0.5 °C using a viscometer (model DV-II+, Brookfield Engineering Labs Inc., Middleboro, Mass., U.S.A.) at 1 rpm and a RV-IV spindle with data gathered in the Wingather V2.1 software (Brookfield Engineering Labs Inc.). For viscosity measurements, 65% oil spreads were excluded from the study since their viscosity values exceeded the allowed upper limit viscosity of the instrument (99999 cP). The pH of each spread sample was measured using an Orion 520 pH meter (Orion Labs, Tucson, Ariz., U.S.A). The water

activity (a_w) of each spread sample was measured using a water activity meter (HygroLab 3, Rotronic A.G, Bassersdorf, Switzerland). Triplicate measurements from two independent batches of each spread treatment were assessed for all physical properties.

Textural properties of mayonnaise-type spreads

For texture analysis, a 25 mL spread sample was poured into a 50 mL beaker and a compression test was applied to the liquid emulsion using an automatic texture analyzer TA-XT2 PLUS (Stable Micro Systems, Godalming, U. K.; Exponent 32 V 1.0.0.13 software) fitted with a 1/2 inch stainless steel ball probe (TA-18). Cohesiveness, springiness, gumminess, resilience and adhesiveness were calculated as described by Bourne (1978). For texture analysis, two independent samples were selected randomly from each of the 18 spread formulations (Table 1).

Consumer evaluation of mayonnaise-type spreads

The research protocol for this study was approved (IRB# HE 15 to 9) by the Louisiana State Univ. Agricultural Center Institutional Review Board. The consumer evaluation was conducted in the Sensory Analysis Laboratory, School of Nutrition and Food Sciences, Louisiana State Univ. Agricultural Center, Baton Rouge, La., U.S.A. The testing room was illuminated with cool, natural, LED lights and evaluations were conducted in individual booths located in the sensory laboratory. Panelists from a pool of faculty, staff, and students at Louisiana State Univ. were recruited and prescreened using the following criteria: 1. regular consumers of mayonnaise products based on self-reported responses and 2. not having taste/smell disorders and/or kidney/liver problems. Consumers (N = 306; 65% females, 35% males) were briefed about the questions, particularly, the sensory attributes and their meanings, and sample handling during the evaluation. A plastic spoon to taste the sample, and crackers, water, and expectoration cups to minimize any residual effects between samples were provided to consumers during the test. A Balanced Incomplete Block (BIB)

Design [t = 18, k = 3, r = 17, b = 102, λ = 2, E = 0.71; generated by PROC OPTEX (SAS Int. 2012)] was used. Each consumer tasted only 3 samples (out of 18). The BIB design was repeated 3 times resulting in a total of 51 observations per mayonnaise-type spread treatment (Table 1). The Compusense five (Compusense Inc., Guelph, Canada) computerized data collection system was used for questionnaire development and data collection.

In the sensory session, consumers were asked to rate saltiness and bitterness of the emulsion (spread) samples using a 100-point labelled magnitude scale (LMS; Green and others 1993). Sensory properties of the spreads were assessed including saltiness, bitterness and thickness/viscosity using a 5-point just about right scale (JAR; 1 = much too weak, 3 = just about right, 5 = much too strong), and overall taste liking using a 9-point hedonic scale (1 = dislike extremely, 5 = neither dislike nor like, 9 = like extremely) (Peryam and Pilgrim 1957). Purchase intent of each spread sample was determined using a binomial (yes/no) scale (Sae-Eaw and others 2007).

Experimental design and statistical analyses

Following the BIB design, a full factorial treatment arrangement (2x3x3) was used to investigate the effects of three factors [2 tastant types (NaCl or KCl) x 3 tastant concentrations (0.5, 0.75 and 1.0% for NaCl or 0.5, 1.0 and 1.5% for KCl) x 3 oil concentrations (45, 55 and 65%)] (Table 1) on physical, textural and sensory properties of the spread samples. Univariate and regression data were analyzed at α = 0.05 using the SAS software 9.1.3 (SAS Inst. 2012). Multivariate data were analyzed using a customized code written in Matlab (Matworks Inc., Matick, Mass., U.S.A.) which allowed finding patterns within data and samples (Fuentes, unpublished). Analysis of Variance (ANOVA) and the post-hoc Tukey's studentized range test were used to locate significant differences among samples. Consumers data from LMS responses were fitted using the response surface methodology (RSM) with a second-order polynomial $\hat{Y} = b_0 + b_1X_1 + b_2X_2 + b_{11}X_1^2 + b_{22}X_2^2 + b_{12}X_1X_2$ model where $\hat{Y}$ was the predicted response (saltiness or bitterness intensity); b_0 was the value of the fitted

response at the center point of the design; b_1 and b_2 were linear regression terms; b_{11} and b_{22} were quadratic regression terms; and b_{12} was the cross product regression term. For JAR and overall taste liking scores, a penalty analysis was performed to measure the negative effect of each sensory attribute (saltiness, bitterness or viscosity) on overall taste liking. Total penalty scores (TPS) were computed by multiplying mean drops [differences between overall taste liking scores rated at “not-JAR” (either too weak or too strong) minus liking scores at JAR] by frequency percentages of consumers at each “not-JAR” category (Walker 2016). Multivariate Analysis of Variance (MANOVA) was used to determine whether significant differences existed among spread samples when inter-correlations among all physical, textural and sensory attributes were tested, simultaneously. For the MANOVA, the single linkage hierarchical clustering algorithm based on Euclidean distances was used to identify clusters of spread samples based on all attributes. Subsequently, principal component analysis (PCA) was performed to demonstrate correlations among the physical/textural/sensory qualities and spread samples as illustrated in the product-attribute bi-plot (Lipkovich and Smith 2001). Logistic regression analysis was performed to predict the positive purchase intent of mayonnaise-type spread samples using the sensory characteristics as regression variables in the model (Torrico and others 2015d).

Results and Discussion

Physical and textural properties of mayonnaise-type spreads

ANOVA of physical and textural characteristics of the spreads is shown in Table 2. The main effects of the experimental design were: 1. Tasant type (NaCl or KCl), 2. Tasant concentration [0.50, 0.75 or 1.00% for NaCl, and 0.50, 1.00 or 1.50% for KCl], and 3. Oil concentration (45, 55 or 65%). Tasant and oil concentrations significantly ($P < 0.05$) affected viscosity and pH. Type of tasant significantly ($P < 0.05$) affected pH. Neither tasant nor oil concentrations significantly affected ($P \geq 0.05$) water activity (data not shown). For all textural parameters, oil concentrations significantly

affected all spreads. Additionally, tastant concentration was a significant ($P < 0.05$) factor for cohesiveness and resilience.

Overall, NaCl spreads had slightly higher viscosity compared to KCl spreads (6400-36395 cP vs. 5685-33545 cP, respectively; Table 3). For NaCl and/or KCl spreads, as oil concentration increased (from 45% to 55%), viscosity increased (11802-29045 cP; Table 3). Increasing tastant concentration had a slight viscosity-increasing effect on NaCl spreads (increase of 950-9145 cP, from 0.50% to 1.00% NaCl) but a viscosity-decreasing effect on KCl spreads (decrease of 8805-16058 cP, from 0.50% to 1.50% KCl). Increasing oil concentrations, increased viscosity and consistency of mayonnaise products (Wendin and others 1999). Changes in viscosity can affect taste perception of oil-in-water emulsions (Prupp and others 2004).

KCl spreads had higher pH values compared to NaCl spreads (4.47-4.55 vs. 4.40-4.42, Table 3). This demonstrated that KCl emulsions are more alkali than NaCl emulsions (Torrico and others 2015a). Tastant and oil concentrations did not have significant effects ($P \geq 0.05$; Table 3) on pH for NaCl spreads. For KCl spreads, increasing tastant concentration (from 0.50% to 1.50% KCl) minimally changed pH. The presence of minerals in emulsions increases the ionic strength of the aqueous phase. This effect leads to a reduction in the electrostatic repulsion between droplets and promotes phase separation. In emulsions, the degree of ionization and pH are important characteristics in determining emulsion stability (Kulmyrzaev and Schubert 2004). Poteau and Argillier (2005) indicated that pH changes may reduce stability of oil-in-water emulsions. Although, in the present study, the stability of the emulsions was not measured, changes in pH can potentially have an effect on shelf-life of spreads. Further studies have to be done to test this hypothesis.

For textural properties of spreads (NaCl and/or KCl), as oil concentration increased (from 45% to 65%), cohesiveness, springiness, gumminess, resilience, and adhesiveness increased (Table 4). On the other hand, type of tastant (NaCl or KCl) and tastant concentration had marginal effects on textural parameters of samples. Wendin and others (1999) indicated that all the rheological

properties of mayonnaise products increased with increasing fat content. Moreover, Liu and others (2007) reported significant decreases in firmness, consistency, cohesiveness and viscosity when 50% oil was replaced with micro-particulated pectin gel in mayonnaise formulations. In the present study, oil had a significant effect on changing viscosity and textural properties of emulsions. On the other hand, the type of tastant was a determinant factor on changing pH of spreads. Water activity (a_w) was not affected by any of these factors, and remained constant for all spreads (0.93-0.95; data not shown).

Sensory analysis of mayonnaise-type spreads

Saltiness

ANOVA for the saltiness intensity of spread samples (Table 2) indicates that the main effects [tastant type, tastant concentration, oil concentration] and the interaction effect between tastant type and oil concentration were significant ($P < 0.05$). Overall, NaCl spreads had slightly higher saltiness intensities compared to KCl spreads (Table 3). As expected, saltiness intensity increased as tastant (NaCl and/or KCl) concentration increased. Generally, saltiness intensity of spreads (NaCl and/or KCl) decreased slightly (3.01-8.26 units) as oil concentration increased (from 45% to 65%; Table 3).

Table 5 shows the estimated parameters of predictive regression models for saltiness of NaCl and KCl spreads. The linear and total model effects were significant ($P < 0.05$) for both spreads. The quadratic effect was only significant for NaCl spreads. Linear parameters for tastant and oil concentrations of NaCl spreads were 69.71 and -4.02, respectively (i.e., an increase of 0.1% NaCl represented an increase of 6.97 intensity units; an increase of 1.0% oil represented a decrease of 4.02 intensity units). Similar to NaCl, KCl linear slope for tastant concentration was positive (8.98), indicating that as tastant concentration increased by 0.1% KCl, saltiness intensity increased by 0.90 units. Contrary to NaCl, increasing oil concentrations (linear slope of 2.00) in KCl spreads slightly

increased saltiness. Predictions on taste using linear correlations are limited by the range of concentrations evaluated in this study (0.5%-1.0% for NaCl, and 0.5%-1.5% for KCl). NaCl saltiness contour plots (Figure 1) indicated that oil exhibited a saltiness-suppressing effect in spreads with 45% to 59% oil; however, oil had a saltiness-enhancing effect in spreads with 60% oil or higher. The opposite pattern occurred with KCl (Figure 1), in which, oil exhibited a saltiness-enhancing effect in spreads with 45% to 53% oil; however, oil showed a saltiness-suppressing effect in spreads with 54% oil or higher.

Hughes and others (1997) reported that oils as hydrophobic compounds can act as physical barriers against sodium migration, disfavoring sodium release. Oil was also found to coat the tongue surface; thus, preventing taste buds from accessing sodium in the oral cavity (Lynch and others 1993). These mechanisms may partially explain the saltiness-suppressing effect imparted by oil for NaCl spreads in the present study. On the other hand, another study reported that oil components may sensitize sodium taste receptors, enhancing saltiness perception (Gilbertson and others 2005). Koriyama and others (2002) hypothesized that lipids in emulsions occupy volume that does not contain NaCl or KCl molecules, which are 100% partitioned in the aqueous phase. Therefore, increased perceived taste intensities are found in emulsions with higher oil concentrations (Kuo and Lee 2014; Koriyama and others 2002). In the present study, this effect may have been the case for KCl spreads with 45-53% oil, in which, increased oil concentrations produced increased saltiness intensities.

Bitterness

ANOVA for the bitterness intensity (Table 2) shows that only the tastant concentration effect was significant ($P < 0.05$) in differentiating spread samples. Although KCl is known to impart bitter taste (Hooge and Chambers 2010), all emulsion systems (including NaCl spreads) presented perceivable bitterness regardless of tastant and oil concentrations (Table 3). Bitterness in NaCl spreads can be

explained due to the presence of other ingredients including vinegar, whey protein and gums in the emulsion formulations. Overall, KCl spreads had slightly higher bitterness intensities compared to that of NaCl spreads (16.90-25.61 vs. 21.24-31.30; Table 3). For KCl spreads, bitterness intensity increased (3.04-10.06 units), as tastant concentration increased (from 0.50% to 1.50% KCl; Table 3). The opposite effect occurred with NaCl spreads, in which, bitterness intensity decreased (2.46-6.94 units) with increasing tastant concentrations (from 0.50% to 1.00% NaCl; Table 3). Generally for both spreads (NaCl and/or KCl), oil had marginally effects on bitterness intensity (Table 3).

For RSM bitterness predictive models (Table 5), the NaCl linear and total model effects were significant ($P < 0.05$). None of the regression effect parameters were significant for KCl (Table 5). The NaCl linear slopes for tastant and oil concentrations were 64.94 and -1.12, respectively. This indicated that increasing NaCl concentration by 0.1%, increased bitterness intensity by 6.49 units. On the other hand, increasing oil concentration by 1.0%, decreased bitterness by 1.12 units. Similar to NaCl, KCl linear slope for tastant concentration was positive (10.48; Table 5) indicating that increasing KCl concentration by 0.1%, marginally increased bitterness intensity by 1.05 units. Contrary to NaCl, oil concentration (linear slope 2.32) in KCl spreads had a slight enhancing effect on bitterness.

Although the NaCl linear slope was positive (64.94; Table 5), its contour plot (Figure 1) indicated that increasing NaCl concentration had, in fact, a suppressing effect on bitterness. This can be explained due to the presence of a marginal negative quadratic effect (-32.24; Table 5) in NaCl spreads, in which, as oil concentration increased, bitterness of samples decreased. Breslin and Bauchamp (1995) demonstrated that sodium suppressed bitterness in solution systems. In the present study, a bitterness-suppressing effect was more noticeable when concentrations of NaCl increased (Table 3).

Thurgood and Martini (2010) indicated that bitterness intensities were lower in emulsion systems compared to solutions. Pripp and others (2004) reported that oil had a limited effect on bitterness

reduction of olive oil phenolic compounds. Metcalf and Vickers (2002) stated that samples with added oil had less bitter taste and more saltiness intensity than those with added water. The suppression of bitterness by fat/oil is not universal and depends on the properties of the molecules responsible for the bitter taste (Coupland and Hayes 2014). Lahtinen and others (2007) showed that lactose (1% or 2%) in combination with sucrose, glucose or galactose suppressed bitter tastes of NaCl/KCl mixtures in emulsions. Keast (2008) stated that the level of caffeine bitterness increased with increases of milk fat content. He attributed this effect to interactions of caffeine molecules with milk proteins and carbohydrates. In the present study, oil had a marginal effect on taste, and the main contributor to reduce bitterness in the systems was the increase of NaCl concentrations. Our previous findings showed that oil had a significant bitterness-suppressing effect in emulsion systems (Torrico and others 2015b; Torrico and others 2015c). Differences among studies may be due to the interaction of other ingredients (vinegar, protein and emulsifiers) that affected taste perception. For example, Keast and Breslin (2003) stated that bitterness in solutions was enhanced with the introduction of sourness, using a binary system at low and medium intensities. Further research is needed to investigate the effects of binary and tertiary interactions on taste perception of oil-in-water emulsions.

Overall taste liking, penalty analysis and purchase intent of mayonnaise-type spreads

ANOVA for the overall taste liking (Table 2) indicated that tastant type and tastant concentration effects were significant ($P < 0.05$) in differentiating spread samples. Overall taste liking scores for all mayonnaise-type spreads (NaCl and/or KCl) were generally low (below 5; Table 3). Overall, NaCl spreads had slightly higher scores compared to that of KCl spreads (Table 3). Oil concentration had a marginal effect on liking scores.

Maximizing acceptability of spreads was not the intended scope of this study. We aimed to evaluate variations in liking depending on changes in oil concentration and the type of tastant used

in the spread formulations. A penalty analysis was performed to identify attributes and samples that were responsible for reductions in acceptance. Figure 2 shows the total penalty scores of spread samples (NaCl and/or KCl) according to viscosity, saltiness, and bitterness. Attributes with scores greater than 0.5 can potentially affect consumer acceptability (Walker 2016). For viscosity, all spreads were generally considered “too thick”, whereas KCl spreads had higher penalty scores compared to NaCl spreads (0.01-1.12 for KCl vs. 0.05-0.64 for NaCl; Figure 2). For saltiness, “too weak” penalty scores (0.18-1.20) were similar compared to that of “too strong” scores (0.19-1.15) for all spreads (Figure 2). There was not a clear trend in penalizing saltiness since consumers taste liking was divided (possibly by likers and dislikers of saltiness among consumers). In general, KCl spreads with higher oil concentrations (55% and 65%) had higher “too weak” saltiness penalty scores compared to other spreads (Figure 2). The NaCl (0.5%)–Oil (65%) spread sample had the lowest saltiness intensity score (16.28; Table 3) and the highest “too weak” saltiness penalty score (1.20) among all NaCl spreads. Similarly, the KCl (0.50%)–Oil (65%) spread sample had the lowest saltiness intensity score (12.25; Table 3) and the second highest “too weak” saltiness penalty score (0.85) among all KCl spreads. Interestingly, the KCl (1.50%)–Oil (45%) spread sample had the highest saltiness intensity score (24.88; Table 3) among all KCl spreads. However, 33.33% (data not shown) of consumers assessed saltiness of this sample as “too weak” and 37.25% (data not shown) of consumers assessed the saltiness of this sample as “too strong” (showing the polarizing effect of saltiness on KCl samples). This resulted in similar penalty scores for both categories (1.19 for “too weak” and 1.15 for “too strong”). All mayonnaise-type spreads were generally considered “too strong” in bitterness, whereas KCl spreads had higher penalty scores (0.61-1.48) compared to those of NaCl spreads (0-1.28). Of all spreads, only NaCl (1.00%)–Oil (55%) and NaCl (0.50%)–Oil (55%) had bitterness penalty scores less than 0.5; in fact, these samples had higher overall taste liking scores (4.21-4.70) compared to other samples (3.36-4.41).

For mayonnaise-type spreads (NaCl or KCl), logistic regression was performed to predict positive purchase intent, considering emulsions characteristics (tastant and oil concentrations) and sensory attributes (saltiness, bitterness, and overall liking) (Table 6). Overall taste liking was the most influential attribute affecting purchase intent for all spreads (odds ratio = 3.554 for NaCl and 3.829 for KCl emulsions). The higher odds ratio for predicting purchase intent of KCl spreads could be explained by the importance of taste liking expressed by consumers in those samples. These results are consistent with the penalty analysis, in which, KCl spreads had higher penalizations on taste liking compared to that of NaCl (Figure 2). Only for NaCl spreads, oil concentration was the second most influential attribute for predicting purchase intent (odds ratio = 1.047), meaning that an increase of 1% in oil concentration represented an increase of 4.7% in the predicated purchasing intent of spreads.

Garcia and others (2009) indicated that mouthfeel and overall liking were the two most influential sensory attributes on the acceptance of mayonnaise-type spreads made with rice bran oil and soy protein. Izidoro and others (2007) reported that regular mayonnaise product possessed higher acceptability scores compared to that of low-fat mayonnaise products. Mihov and others (2012) reported that high fat mayonnaise products obtained higher acceptability scores for appearance and taste compared to low fat product versions. In our present study, overall taste liking of the spreads was strongly affected by type of tastant. Generally, spreads containing KCl were highly penalized in taste liking for being too bitter. The lower taste acceptability resulted in a decrease in purchase intent of spreads (Lawless & Heymann, 2010). However, oil concentration also played an important role on assessing purchase intent of spreads containing NaCl.

Multivariate analysis

The results obtained by the cluster analysis of 18 mayonnaise-type spreads considering 3 sensory (saltiness, bitterness and overall liking), 3 physical (pH, water activity, and viscosity) and 5 textural

(cohesiveness, gumminess, springiness, resilience, and adhesiveness) attributes are presented as the dendrogram in Figure 3. Two main cluster groups were observed: (1) 45% and 55% oil spreads and (2) 65% oil spreads. These results indicated that the main differentiating factor among spreads was the oil concentration. NaCl (1.00%)–Oil (45%) and NaCl (0.75%)–Oil (45%) had the smallest inter-cluster distance indicated by the vertical line linking them. Subsequently, other minor clusters (distance between clusters < 3; Figure 3) were formed among 45% and 55% oil spreads. The bi-plot (Figure 4) describes the principal component analysis, considering the relative position of spread samples and sensory/physical/textural attributes (70.85% of total variability). In terms of the sensory attributes, the bitterness vector points to the opposite direction of overall taste liking vector, meaning that these two attributes were negatively correlated (a higher bitterness produced a lower overall taste liking). On the other hand, saltiness was marginally correlated to bitterness and overall taste liking. For physical attributes, pH was negatively correlated with water activity. Viscosity, on the other hand, was not correlated with any other physical attribute. For textural attributes, cohesiveness, springiness, and resilience were positively correlated (higher cohesiveness produced higher springiness and resilience). Viscosity was positively correlated with cohesiveness, gumminess, springiness and resilience. Interestingly, pH was positively correlated with bitterness and negatively correlated with overall taste liking. Our previous investigation demonstrated that KCl systems (solutions and emulsions) possessed higher pH and bitterness values compared to that of NaCl systems (Torrico and others 2015a). Fontoin and others (2008) reported that increasing pH values did not have a significant effect on bitterness of wine solutions. Seki and others (1990) reported that increasing pH values of solutions produced decreases in saltiness perception. Further work has to be done to elucidate the effects of pH on taste perception of oil-in-water emulsions.

In the present study, two mayonnaise-type spread groups were clearly separated along principal component 1 (65% oil and 45-55% oil spreads; Figure 4), considering all sensory/physical/textural attributes altogether. This result is in agreement with the finding from the cluster analysis (Figure 3).

For the PCA (Figure 4), textural (cohesiveness, gumminess, springiness, and resilience) and viscosity parameters were the larger contributors to the differences among spread samples.

Collectively, based on Tables 2, 5 and 6, and Figures 1 and 4, the results indicated that oil concentration affected saltiness, viscosity, pH and consistency/texture of mayonnaise-type spreads. Moreover, oil concentration was a significant factor for predicting purchase intent of spreads containing NaCl, and was the main factor that contributed to the overall differences of the spreads, considering all sensory, physical and textural attributes, altogether.

Conclusions

This study demonstrated that oil and tastant (NaCl and/or KCl) concentrations had significant effects on saltiness, viscosity, and pH. Generally, as oil concentration increased, saltiness perception slightly decreased for spreads. Oil had a marginal effect on bitterness. Increasing oil concentration increased viscosity. Spreads containing KCl had higher bitterness than spreads containing NaCl. Bitterness of spreads containing KCl increased with increasing oil concentrations, which resulted in higher penalizations for overall taste liking. Purchase intent was significantly affected by taste liking for all spreads but oil concentration was also a significant factor in the purchase decision of spreads containing NaCl. This study demonstrated that increasing oil and tastant concentrations affected consumers' taste perception (saltiness and bitterness) and spreads' physical properties including pH and viscosity. These findings are useful for understanding consumers' taste perception of oil-in-water emulsion products.

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Table 1 Formulations of mayonnaise-type spreads made with canola oil

Formulations ¹	Oil (%)	NaCl (%)	KCl (%)	Water (%)
NaCl(0.50%)-Oil(45%)	45	0.50	0.00	39.45
NaCl(0.75%)-Oil(45%)	45	0.75	0.00	39.20

NaCl(1.00%)-Oil(45%)	45	1.00	0.00	38.95
NaCl(0.50%)-Oil(55%)	55	0.50	0.00	29.45
NaCl(0.75%)-Oil(55%)	55	0.75	0.00	29.20
NaCl(1.00%)-Oil(55%)	55	1.00	0.00	28.95
NaCl(0.50%)-Oil(65%)	65	0.50	0.00	19.45
NaCl(0.75%)-Oil(65%)	65	0.75	0.00	19.20
NaCl(1.00%)-Oil(65%)	65	1.00	0.00	18.95
KCl(0.50%)-Oil(45%)	45	0.00	0.50	39.45
KCl(1.00%)-Oil(45%)	45	0.00	1.00	38.95
KCl(1.50%)-Oil(45%)	45	0.00	1.50	38.45
KCl(0.50%)-Oil(55%)	55	0.00	0.50	29.45
KCl(1.00%)-Oil(55%)	55	0.00	1.00	28.95
KCl(1.50%)-Oil(55%)	55	0.00	1.50	28.45
KCl(0.50%)-Oil(65%)	65	0.00	0.50	19.45
KCl(1.00%)-Oil(65%)	65	0.00	1.00	18.95
KCl(1.50%)-Oil(65%)	65	0.00	1.50	18.45

¹ All treatments had fixed concentrations of vinegar (8.90%), whey protein isolate (5.4%), and Tic Gum (0.75%).

Table 2 ANOVA¹ table for the sensory, physical, and textural characteristics of spreads

Effects ¹	Sensory evaluation						Physical characteristics			
	Saltiness		Bitterness		Overall taste		Viscosity (cP) ²		pH	
	F Value ³	Pr > F ³	F Value ³	Pr > F ³	F Value ³	Pr > F ³	F Value ³	Pr > F ³	F Value ³	Pr > F ³
Tastant (A)	9.11	0.0027	3.49	0.0623	16.31	<.0001	0.00	0.9596	804.60	<.0001
% tastant (B(A)) ⁴	14.50	<.0001	4.19	0.0061	3.67	0.0122	4.76	0.0069	10.63	<.0001
% oil (C)	4.88	0.0080	0.05	0.9517	2.24	0.1079	193.51	<.0001	31.48	<.0001
A x C	3.11	0.0454	0.93	0.3960	1.12	0.3256	12.44	0.0012	17.72	<.0001
B x C (A)	1.53	0.1331	1.12	0.3500	1.16	0.3217	4.21	0.0042	3.83	0.0009
Effects [*]	Instrumental texture characteristics									
	Cohesiveness		Springiness (%)		Gumminess (N)		Resilience (%)		Adhesiveness (N s)	
	F Value ³	Pr > F ³	F Value ³	Pr > F ³	F Value ³	Pr > F ³	F Value ³	Pr > F ³	F Value ³	Pr > F ³
Tastant (A)	2.40	0.1271	0.24	0.6228	0.05	0.8217	6.63	0.0129	0.01	0.9304
% tastant (B(A)) ⁴	8.49	0.0001	0.73	0.5382	0.40	0.7533	7.59	0.0003	0.27	0.8493
% oil (C)	175.88	<.0001	35.86	<.0001	804.07	<.0001	76.06	<.0001	617.87	<.0001
A x C	0.87	0.4264	0.57	0.5717	1.33	0.2722	0.58	0.5620	0.55	0.5793

¹ ANOVA, Analysis of variance [A = 2 tastants (NaCl and KCl), B = 3 percentages of tastants (0.5, 0.75 and 1.0% for NaCl; 0.5, 1.0 and 1.5% for KCl), C = 3 percentages of oil (45, 55 and 65%)].

² For viscosity, 65% oil emulsions were excluded from the ANOVA since their viscosity values were greater than the allowed upper limit viscosity of the instrument (99999 cP).

³ F value, Mean square/Mean square error. Effects were considered significant when the probability $Pr > F$ was less than 0.05 (Bolded and italicized probabilities).

⁴ For bitterness, the percentage of tastant (B) effect is nested within the tastant (A) = B(A).

Table 3 Mean values¹ for spreads sensory and physical characteristics

Emulsion parameters			Sensory evaluation			Physical characteristics	
Tastant	(%) of oil	(%) of tastant	Saltiness	Bitterness	Overall taste	Viscosity (cP) ²	pH
NaCl	45%	0.50%	21.06 ± 2.09 ^{cdefg}	24.25 ± 2.76 ^{bcde}	3.60 ± 0.24 ^{cd}	6400.00 ± 2563.42 ^g	4.42 ± 0.01 ^{ef}
		0.75%	23.16 ± 2.11 ^{bcd}	25.61 ± 2.77 ^{abcde}	3.58 ± 0.25 ^{cd}	7605.00 ± 2563.42 ^{fg}	4.42 ± 0.01 ^{ef}
		1.00%	29.89 ± 2.07 ^a	20.70 ± 2.73 ^{ef}	4.13 ± 0.24 ^{abc}	7350.00 ± 2563.42 ^{fg}	4.41 ± 0.01 ^{ef}
	55%	0.50%	16.66 ± 2.08 ^{fgh}	23.84 ± 2.76 ^{bcde}	4.21 ± 0.24 ^{abc}	27250.00 ± 2563.42 ^{bc}	4.41 ± 0.01 ^{fg}
		0.75%	19.24 ± 2.07 ^{defg}	25.55 ± 2.76 ^{abcde}	3.46 ± 0.25 ^d	35135.00 ± 2563.42 ^a	4.40 ± 0.01 ^g
		1.00%	22.81 ± 2.03 ^{bcde}	16.90 ± 2.72 ^f	4.70 ± 0.24 ^a	36395.00 ± 2563.42 ^a	4.41 ± 0.01 ^{efg}
	65%	0.50%	16.28 ± 2.03 ^{hg}	24.43 ± 2.68 ^{bcde}	4.31 ± 0.24 ^{ba}	-	4.41 ± 0.01 ^{fg}
		0.75%	26.88 ± 2.06 ^{ab}	22.81 ± 2.79 ^{cdef}	3.98 ± 0.24 ^{bcd}	-	4.42 ± 0.01 ^e
		1.00%	21.63 ± 2.05 ^{bcdefg}	21.97 ± 2.69 ^{cdef}	4.30 ± 0.24 ^{ab}	-	4.41 ± 0.01 ^{efg}
KCl	45%	0.50%	17.53 ± 2.07 ^{efgh}	21.24 ± 2.71 ^{def}	3.75 ± 0.24 ^{bcd}	14490.00 ± 2563.42 ^{ef}	4.50 ± 0.01 ^c
		1.00%	20.52 ± 2.05 ^{cdefg}	23.56 ± 2.72 ^{bcde}	3.63 ± 0.24 ^{cd}	6872.25 ± 2563.42 ^g	4.50 ± 0.01 ^c
		1.50%	24.88 ± 2.03 ^{abc}	31.30 ± 2.75 ^a	3.47 ± 0.24 ^d	5685.00 ± 2563.42 ^g	4.50 ± 0.01 ^c
	55%	0.50%	16.47 ± 2.04 ^{hg}	25.51 ± 2.74 ^{abcde}	3.77 ± 0.24 ^{bcd}	33545.00 ± 2563.42 ^{ab}	4.47 ± 0.01 ^d
		1.00%	22.47 ± 2.08 ^{bcde}	27.43 ± 2.74 ^{abcd}	3.36 ± 0.25 ^d	22118.00 ± 2563.42 ^{cd}	4.49 ± 0.01 ^c
		1.50%	22.65 ± 2.08 ^{bcde}	29.83 ± 2.69 ^{ab}	3.60 ± 0.24 ^{cd}	17487.00 ± 2563.42 ^{de}	4.51 ± 0.01 ^c
	65%	0.50%	12.25 ±	24.81 ±	3.61 ±	-	4.51 ±

		2.06 ^h	2.73 ^{abcde}	0.24 ^{cd}		0.01 ^c
	1.00%	18.56 ± 2.08 ^{defg}	25.09 ± 2.77 ^{abcde}	3.82 ± 0.25 ^{bcd}	-	4.53 ± 0.01 ^b
	1.50%	21.87 ± 2.05 ^{bcdef}	27.85 ± 2.70 ^{abc}	3.83 ± 0.24 ^{bcd}	-	4.55 ± 0.01 ^a

¹ Data are represented as mean and standard error values (N=51 for sensory and N=2 for physical characteristics). For saltiness and bitterness, values are based on a 100-points Labeled Magnitude Scale (LMS) scale. Overall taste liking scores were based on a 9-point hedonic scale.

^{a-h} Mean values with the same letter within the same column are not significantly different ($P \geq 0.05$).

² For viscosity, 65% oil emulsions were excluded since their viscosity values were greater than the allowed upper limit viscosity of the instrument (99999 cP).

Table 4 Mean values¹ for spreads textural characteristics

Emulsion parameters			Textural characteristics				
Tastant	(%) of oil	(%) of tastant	Cohesiveness	Springiness (%)	Gumminess (N)	Resilience	Adhesiveness
NaCl	45%	0.50%	0.63 ± 0.02 ^{de}	86.90 ± 2.29 ^{cdef}	0.25 ± 0.33 ^c	0.12 ± 0.72 ^d	-1.41 ± 2.17 ^a
		0.75%	0.69 ± 0.02 ^{cd}	90.35 ± 2.29 ^{bcd}	0.26 ± 0.33 ^c	0.12 ± 0.72 ^d	-0.69 ± 2.17 ^a
		1.00%	0.69 ± 0.02 ^{cd}	82.92 ± 2.29 ^f	0.26 ± 0.33 ^c	0.11 ± 0.72 ^d	-0.50 ± 2.17 ^a
	55%	0.50%	0.70 ± 0.02 ^c	91.35 ± 2.29 ^{abcd}	0.33 ± 0.33 ^c	2.88 ± 0.72 ^c	-5.65 ± 2.17 ^{ab}
		0.75%	0.71 ± 0.02 ^c	93.06 ± 2.29 ^{abc}	0.26 ± 0.33 ^c	5.35 ± 0.72 ^{ab}	-9.05 ± 2.17 ^b
		1.00%	0.71 ± 0.02 ^c	92.63 ± 2.29 ^{abc}	0.33 ± 0.33 ^c	3.21 ± 0.72 ^c	-6.33 ± 2.17 ^{ab}
	65%	0.50%	0.85 ± 0.02 ^b	95.86 ± 2.29 ^{ab}	7.12 ± 0.33 ^a	5.45 ± 0.72 ^{ab}	-45.37 ± 2.17 ^{de}
		0.75%	0.89 ± 0.02 ^{ab}	97.02 ± 2.29 ^a	6.00 ± 0.33 ^b	4.52 ± 0.72 ^{bc}	-39.46 ± 2.17 ^{cd}
		1.00%	0.92 ± 0.02 ^a	97.44 ± 2.29 ^a	6.08 ± 0.33 ^b	4.38 ± 0.72 ^{bc}	-38.70 ± 2.17 ^c
	45%	0.50%	0.63 ± 0.02 ^{de}	85.96 ± 2.29 ^{def}	0.28 ± 0.33 ^c	0.13 ± 0.72 ^d	-3.92 ± 2.17 ^{ab}
		1.00%	0.67 ± 0.02 ^{cde}	83.52 ± 2.29 ^{ef}	0.21 ± 0.33 ^c	0.11 ± 0.72 ^d	-0.79 ± 2.17 ^a
		1.50%	0.71 ± 0.02 ^c	86.30 ± 2.29 ^{def}	0.28 ± 0.33 ^c	0.09 ± 0.72 ^d	-0.75 ± 2.17 ^a
KCl	55%	0.50%	0.61 ± 0.02 ^e	88.01 ± 2.29 ^{cdef}	0.26 ± 0.33 ^c	7.37 ± 0.72 ^a	-7.65 ± 2.17 ^b
		1.00%	0.71 ± 0.02 ^c	92.14 ± 2.29 ^{abcd}	0.28 ± 0.33 ^c	3.28 ± 0.72 ^c	-6.03 ± 2.17 ^{ab}
		1.50%	0.73 ±	89.23 ±	0.22 ± 0.33 ^c	0.13 ±	-3.46 ±

		0.02 ^c	2.29 ^{cde}		0.72 ^d	2.17 ^{ab}
	0.50%	0.88 ± 0.02 ^{ab}	96.58 ± 2.29 ^{ab}	6.14 ± 0.33 ^b	5.69 ± 0.72 ^{ab}	-37.46 ± 2.17 ^c
65%	1.00%	0.90 ± 0.02 ^{ab}	97.07 ± 2.29 ^a	7.44 ± 0.33 ^a	6.02 ± 0.72 ^{ab}	-42.74 ± 2.17 ^{cde}
	1.50%	0.90 ± 0.02 ^{ab}	97.15 ± 2.29 ^a	7.10 ± 0.33 ^a	4.58 ± 0.72 ^{bc}	-46.36 ± 2.17 ^e

¹ Data are represented as mean and standard error values (N=2). ^{a-f} Mean values with the same letter within the same column are not significantly different ($P \geq 0.05$).

Table 5 Response surface methodology effects and estimated parameters for spreads sensory tastes

Sensory taste	Tastant	Regression effects ¹				Residual ¹	Regression parameters estimates ²
		Linear	Quadratic	Cross product	Total model	Lack of fit	
		Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	
Saltiness	NaCl	0.0035	0.0249	0.2427	0.0013	0.0243	104.36+69.71X ₁ -4.02X ₂ -21.29X ₁ X ₂ -0.50X ₁ X ₂ +0.04X ₂ X ₂
	KCl	<.0001	0.3828	0.7377	0.0001	0.6053	-38.81+8.98X ₁ +2.00X ₂ -2.38X ₁ X ₂ +0.07X ₁ X ₂ -0.02X ₂ X ₂
Bitterness	NaCl	0.0054	0.3992	0.2790	0.0197	0.6888	33.85+64.94X ₁ -1.12X ₂ -32.24X ₁ X ₂ -0.54X ₁ X ₂ +0.01X ₂ X ₂
	KCl	0.1752	0.6230	0.4932	0.4277	0.3498	-44.99+10.48X ₁ +2.32X ₂ +2.46X ₁ X ₂ -0.20X ₁ X ₂ -0.02X ₂ X ₂

¹ Effects were considered significant when the probability Pr > F was less than 0.05 (Bolded and italicized probabilities).

² For NaCl saltiness or bitterness, X₁ = % of NaCl and X₂ = % of oil; for KCl saltiness or bitterness, X₁ = % of KCl and X₂ = % of oil.

Table 6 Odds ratio estimates and probabilities* for predicting purchase intent of the spreads

Sensory Attributes	Tastant			
	NaCl		KCl	
	Estimate	Pr > χ^2 *	Estimate	Pr > χ^2
Tastant concentration	1.232	0.7680	1.084	0.8309
Oil concentration	1.047	0.0138	0.997	0.8891
Saltiness intensity	1.006	0.6127	1.002	0.8531

Bitterness intensity	0.995	0.6781	1.016	0.1276
Overall taste liking	3.554	<.0001	3.829	<.0001

Figure 1 Response contours for saltiness and bitterness intensities¹ with design points and surface plots for NaCl and KCl mayonnaise-type spreads

¹ A total of 306 consumer panelists participated in the sensory evaluation generating N=51 repetitions per design data point. See Table 2 footnote for % oil, % NaCl and % KCl in oil-in-water emulsions.

Figure 2 Total penalty scores in overall taste liking of NaCl and KCl emulsions (spreads) for viscosity, saltiness and bitterness

* Based on the logistic regression analysis (LRA), using a full model with 2 product-composition parameters (tastant and oil percentages) and 3 sensory attributes (saltiness, bitterness and overall taste liking). The analysis of maximum likelihood estimates was used to obtain the parameter estimates. Odds ratios represent the positive or neutral over negative purchase intent responses.

** Parameter estimates were considered significant when the probability of the Wald χ^2 was < 0.05.

Figure 3 Dendrogram from cluster analysis of different emulsion systems (NaCl and KCl) considering sensory, physical and textural attributes.

Figure 4 Principal component analysis (PCA) product-attribute bi-plot: A score plot of the first principal component (PC1) and second principal component (PC2) visualizing treatments (NaCl and KCl emulsion systems) and sensory, physical and textural attributes. Dashed line vectors represent sensory attributes and solid line vectors represent physical and textural attributes

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