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Inulin, KCL, and Flavor Enhancers: An Efficient Combination to Produce Prebiotic and Low-Sodium Burgers

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In this study, prebiotic and low-sodium burgers were produced. In the first experiment, burgers were elaborated with 0, 3, 6, 9, and 12% inulin. The addition of up to 9% inulin did not affect the sensory quality, increased yield and reduced shrinkage. Thus, in the second experiment, prebiotic burgers were produced with 9% inulin and a sodium reformulation was performed by replacing 60% NaCl with KCl and adding monosodium glutamate (MG) and/or liquid smoke (LS). The replacement of NaCl for KCl impaired the sensory quality of the burgers. The isolated or combined addition of MG and LS reduced the sensory defects caused by KCl. Thus, prebiotic and low-sodium burgers with high technological and sensory quality can be produced using 9% inulin, 1% NaCl, 1.5% KCl, 0.2% MG, and 0.1% LS.

Keywords: healthier meat products, monosodium glutamate, liquid smoke, technological quality, sensory quality

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INTRODUCTION

The consumption of foods rich in bioactive compounds is an excellent strategy to strengthen the immune system and improve the quality of life of the population. This fact has caused an increase in the world demand for healthier foods and challenged the meat industry to develop differentiated products. The reformulation through the substitution of harmful compounds to health and the incorporation of bioactive compounds, such as prebiotic fibers, is an efficient approach to produce healthier meat products.

In addition to improving nutritional quality, fibers increase water retention (do Amaral et al., 2015; Henning et al., 2016; Han and Bertram, 2017) which can be useful to improve the technological and sensory quality of low -fat and/or low-sodium meat products. In this context, inulin has been used successfully as a fat substitute in meat products (Álvarez and Barbut, 2013; Keenan et al., 2014a). Inulin is considered a prebiotic fiber because it is not digestible and selectively stimulates the multiplication and activity of beneficial intestinal bacteria (Saad et al., 2011). Thus, inulin intake improves the immune system and also reduces the risk of diseases such as colon cancer and osteoporosis (Wan et al., 2020; Bakirhan and Karabudak, 2021).

Reducing the sodium content is another way of giving healthier properties to meat products, since the correlation between excessive sodium intake and the occurrence of cardiovascular diseases is well-documented (Cappuccio et al., 2019). NaCl replacement by KCl is one of the most efficient strategies to decrease the sodium content of meat products (Pateiro et al., 2021). However, sensory quality can be impaired depending on the type of meat product and the level of substitution (Saldaña et al., 2021). Thus, the use of flavor enhancers in conjunction with KCl is an approach that should be researched to improve the sensory quality of low-sodium meat products.

Monosodium glutamate (MG) and liquid smoke (LS) are flavor enhancers that have already been used successfully in isolation to compensate for sensory defects caused by KCl in meat products (Dos Santos et al., 2014; Santos Alves et al., 2017). However, the combined use of both compounds is still little explored. Thus, in the first part of this study the effect of adding 0, 3, 6, 9, and 12% inulin on the technological and sensory quality of burgers was evaluated (Experiment 1). Subsequently, prebiotic burgers were produced with 9% inulin and a sodium reformulation was performed by replacing 60% NaCl with KCl and adding MG and LS. The effect of this sodium reformulation on the sensory quality of burgers was evaluated (Experiment 2).

MATERIALS AND METHODS

Treatments and Processing of Burgers

In Experiment 1 burgers were produced with the addition of 0, 3, 6, 9, and 12% inulin (Orafti®HP, Beneo-Orafti, São Paulo, SP). In Experiment 2, burgers were produced with 9% inulin and 60% replacement of NaCl by KCl. In addition, MG and LS were also added (**Table 1**). Beef was ground using a 3 mm plate and mixed with the remaining ingredients. Burgers (60 g) with 11 cm diameter and 2.5 cm thickness were manufactured using conventional burger-maker. The burgers were immediately frozen and stored at −18°C until the time of analysis.

Chemical Composition

The chemical composition of the raw burgers was determined in triplicate using three samples for each treatment. The moisture content was determined by drying in an oven at 105 ± 2°C; the nitrogen content was determined by the Kjeldahl method and the protein content estimated by multiplying the nitrogen content by 6.25; the fat content was determined by the Soxhlet method using petroleum ether, and the ash content was determined by incineration in a muffle furnace at 550°C (AOAC, 2005).

Cooking Properties

Three burgers of each treatment were cooked in a hot plate (150°C), until a core temperature of 72°C. The samples were cooled at room temperature (25°C) before weighing. Yield was determined by weighing each burger before and after cooking, which was defined as the cooked weight divided by the uncooked weight, and then multiplied by 100 (Murphy et al., 1975). The shrinkage was calculated using the following equation: % Shrinkage = [(Diameter of the raw sample - diameter of the cooked sample) / diameter of the raw sample)] × 100 (Berry, 1992).

Instrumental Color

The color of raw burgers was measured using a Minolta CR-400 colorimeter (Konica Minolta Sensing Inc., Japan), using spectral reflectance included as calibration mode, illuminant D65, and observation angle of 10°. The color variables were measured at four points on the central part of the cut surface of three samples. L^*, a^*, and b^* values were determined as indicators of lightness, redness, and yellowness, respectively. Whiteness values were calculated according to CIE values (L * a * b *) as described by Park (1994):

$$\text{Whiteness} = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2}$$

Consumer Test

A pilot consumer test was performed on the burgers elaborated in Experiments 1 and 2. A sensory acceptance test using a 9 point hedonic scale was performed (1 - disliked extremely; 9 - liked extremely) (Meilgaard et al., 2006). The liking of color, aroma, flavor and texture, as well as, overall liking was evaluated by 40 consumers (Franco et al., 2019). Before the consumer test, the burgers were cooked in a hot plate (150°C), until a temperature of 72°C. Each burger was cut into four 4×4×2.5 cm serving samples, wrapped individually in aluminum foil, and served warm to the consumers. Samples were coded with three-digit random numbers and presented to the consumers, balancing the effect of order of presentation and the first-order carry-over effects, according to MacFie et al. (1989). Water at room temperature and salted crackers were provided for palate cleansing. The test was performed in normalized booths under fluorescence lighting and all participants signed an informed consent to participate in the research.

Statistical Analysis

The experimental design used was completely randomized. The entire experiment was replicated two times in two different days and all analyzes were performed at least in triplicate. The data

TABLE 1 | Formulation (%) of prebiotic and low-sodium burgers.

	Experiment 1					Experiment 2				
	Control	F3	F6	F9	F12	C_{NaCl}	C_{KCl}	MG	LS	MG+LS
Beef	100	100	100	100	100	100	100	100	100	100
Inulin*	0	3	6	9	12	9	9	9	9	9
NaCl*	2.5	2.5	2.5	2.5	2.5	2.5	1.0	1.0	1.0	1.0
KCl*	–	–	–	–	–	–	1.5	1.5	1.5	1.5
Liquid smoke*	–	–	–	–	–	–	–	–	0.1	0.1
Monosodium glutamate*	–	–	–	–	–	–	–	0.2	–	0.2

Added in relation to beef.

TABLE 2 | Chemical composition (%) of prebiotic burgers.

	Moisture	Protein	Fat	Ash
Control	63.7 $\pm 0.3^{a}$	19.1 $\pm 1.7^{a}$	2.5 $\pm 0.1^{b}$	6.88 $\pm 0.2^{b}$
F3	63.9 $\pm 0.1^{a}$	17.5 $\pm 0.5^{a}$	2.4 $\pm 0.1^{b}$	7.64 $\pm 0.1^{ab}$
F6	62.4 $\pm 0.1^{b}$	17.4 $\pm 1.4^{a}$	2.2 $\pm 0.1^{b}$	8.64 $\pm 0.1^{a}$
F9	60.8 $\pm 0.1^{c}$	18.3 $\pm 1.3^{a}$	2.4 $\pm 0.2^{b}$	9.05 $\pm 0.1^{a}$
F12	57.5 $\pm 0.1^{d}$	18.5 $\pm 0.6^{a}$	2.5 $\pm 1.3^{b}$	9.88 $\pm 0.2^{a}$

**Values represent the mean (± standard deviation). Means followed by the same letter, in the same column, do not show significant difference (P > 0.05) by the Tukey test. Control: 0% inulin; F3: 3% inulin; F6: 6% inulin; F9: 9% inulin; F12: 12% inulin.*

TABLE 3 | Yield and shrinkage of prebiotic burgers.

	Yield (%)	Shrinkage (%)
Control	61.3 $\pm 2.1^{b}$	27.6 $\pm 2.28^{a}$
F3	62.1 $\pm 2.2^{ab}$	26.2 $\pm 2.39^{a}$
F6	64.9 $\pm 1.5^{a}$	24.9 $\pm 2.07^{b}$
F9	63.6 $\pm 1.7^{a}$	23.9 $\pm 3.70^{b}$
F12	65.9 $\pm 0.7^{a}$	21.2 $\pm 2.67^{c}$

**Values represent the mean (± standard deviation). Means followed by the same letter, in the same column, do not show significant difference (P > 0.05) by the Tukey test. Control: 0% inulin; F3: 3% inulin; F6: 6% inulin; F9: 9% inulin; F12: 12% inulin.*

TABLE 4 | Instrumental color of prebiotic burgers.

	L*	a*	b*	Whiteness
Control	50.7 $\pm 2.5^{b}$	5.5 $\pm 0.4^{d}$	8.3 $\pm 0.7^{a}$	49.7 $\pm 2.4^{b}$
F3	53.2 $\pm 2.1^{ab}$	5.8 $\pm 0.4^{cd}$	8.6 $\pm 0.5^{a}$	52.0 $\pm 2.1^{ab}$
F6	52.7 $\pm 2.0^{ab}$	6.4 $\pm 0.4^{bc}$	8.5 $\pm 1.1^{a}$	51.5 $\pm 1.5^{ab}$
F9	55.0 $\pm 2.1^{a}$	6.9 $\pm 0.8^{ab}$	8.8 $\pm 0.8^{a}$	53.6 $\pm 1.9^{a}$
F12	54.5 $\pm 2.2^{a}$	7.5 $\pm 0.9^{a}$	9.3 $\pm 1.0^{a}$	52.9 $\pm 2.1^{a}$

**Values represent the mean (± standard deviation). Means followed by the same letter, in the same column, do not show significant difference (P > 0.05) by the Tukey test. Control: 0% inulin; F3: 3% inulin; F6: 6% inulin; F9: 9% inulin; F12: 12% inulin.*

TABLE 5 | Consumer's acceptance of prebiotic burgers.

	Color	Aroma	Flavor	Texture	Overall liking
Control	7.7 $\pm 0.9^{a}$	7.5 $\pm 1.2^{a}$	7.7 $\pm 1.1^{a}$	7.6 $\pm 1.6^{a}$	7.6 $\pm 1.1^{a}$
F3	7.6 $\pm 1.1^{a}$	7.5 $\pm 1.0^{a}$	7.6 $\pm 0.8^{a}$	7.3 $\pm 1.2^{ab}$	7.5 $\pm 0.9^{a}$
F6	7.7 $\pm 1.0^{a}$	7.3 $\pm 1.2^{a}$	7.5 $\pm 0.9^{a}$	7.3 $\pm 1.3^{ab}$	7.5 $\pm 0.9^{a}$
F9	7.9 $\pm 1.1^{a}$	7.3 $\pm 1.7^{a}$	7.6 $\pm 1.2^{a}$	7.2 $\pm 0.9^{ab}$	7.6 $\pm 0.9^{a}$
F12	7.7 $\pm 1.0^{a}$	7.2 $\pm 1.5^{a}$	7.1 $\pm 1.6^{a}$	6.8 $\pm 1.6^{b}$	6.9 $\pm 1.5^{b}$

**Values represent the mean (± standard deviation). Means followed by the same letter, in the same column, do not show significant difference (P > 0.05) by the Tukey test. Control: 0% inulin; F3: 3% inulin; F6: 6% inulin; F9: 9% inulin; F12: 12% inulin.*

TABLE 6 | Consumer study of prebiotic and low-sodium burgers.

	Color	Aroma	Flavor	Texture	Overall liking
C_{NaCl}	7.8 $\pm 1.2^{a}$	7.6 $\pm 1.4^{a}$	7.6 $\pm 1.5^{a}$	7.6 $\pm 1.3^{a}$	7.6 $\pm 1.3^{b}$
C_{KCl}	8.0 $\pm 0.9^{a}$	7.7 $\pm 0.9^{a}$	6.2 $\pm 2.5^{b}$	6.2 $\pm 2.4^{b}$	6.1 $\pm 1.4^{c}$
MG	7.7 $\pm 1.0^{a}$	7.7 $\pm 0.9^{a}$	7.5 $\pm 1.1^{a}$	7.7 $\pm 0.9^{a}$	7.6 $\pm 0.9^{ab}$
LS	7.9 $\pm 0.9^{a}$	7.7 $\pm 0.9^{a}$	7.5 $\pm 1.1^{a}$	7.5 $\pm 1.2^{a}$	7.6 $\pm 1.0^{b}$
MG+LS	8.0 $\pm 1.0^{a}$	7.9 $\pm 1.2^{a}$	8.1 $\pm 1.3^{a}$	8.0 $\pm 1.1^{a}$	8.2 $\pm 1.1^{a}$

**Values represent the mean (± standard deviation). Means followed by the same letter, in the same column, do not show significant difference (P > 0.05) by the Tukey test. C_{NaCl}: 9% inulin and 2.5% NaCl; C_{KCl}: 9% inulin, 1% NaCl and 1.5% KCl; MG: 9% inulin, 1% NaCl, 1.5% KCl and 0.2% MG; LS: 9% inulin, 11% NaCl and 1.5% KCl and 0.1% liquid smoke; MG + LS: 9% inulin, % NaCl and 1.5% KCl; MG, 0.2% MG and 0.1% liquid smoke.*

were evaluated through analysis of variance (ANOVA) using the XLStat statistical program. The means were compared by the Tukey test, considering the significance level of 5% ($P < 0.05$).

RESULTS AND DISCUSSION

Experiment 1

The results of the chemical composition of prebiotic burgers are shown in **Table 2**. The chemical composition of all treatments was in accordance with the parameters required by Brazilian legislation (Brasil, 2000), which establishes a minimum content of 15% protein and a maximum content of 23% fat. The addition of 6–12% inulin decreased the moisture content and increased the ash content of the burgers ($P < 0.05$). No difference ($P < 0.05$) was found in the levels of protein and fat between Control and the reformulated burgers. All treatments can be claimed as "low fat" according to the current European Regulation on nutrition claims (European Parliament, 2006) because contains no more than 3 g of fat per 100 g for solids. In addition, the burgers also can be claimed as "high protein" since that at least 20% of the energy value of the product (132.5 ± 9.3 kcal/100 g) is provided by protein.

The percentage of yield and shrinkage of prebiotic burgers are shown in **Table 3**. The addition of 6–12% inulin increased the yield and decreased the shrinkage of the burgers as compared to the control ($P < 0.05$). A similar trend was reported by Afshari et al. (2017) and Bis-Souza et al. (2018) who added prebiotic fibers in low-fat beef burgers. The inulin's ability to retain water can be attributed to its long chain of oligosaccharides rich in hydroxyl groups that interact with water by hydrogen bonds. Thus, a crystallized and stable three-dimensional gel network is formed (Barclay et al., 2010; Keenan et al., 2014b).

The instrumental color values of burgers enriched with inulin are shown in **Table 4**. The addition of inulin (9 and 12%) increased ($P < 0.05$) the lightness (L*) of the burgers. The a* values (redness) were also affected by the addition of inulin. The treatments with addition of 6–12% inulin (F6, F9, and F12) showed a higher redness than control. The yellowness (b*) was not affected by the addition of inulin. On the other hand, the results of the Whiteness parameter demonstrated that the addition of 9 and 12% inulin made the burgers lighter (greater Whiteness). This outcome is in agreement with those observed by Álvarez and Barbut (2013) who noticed that the addition of high levels of fiber affect the instrumental color of meat products.

The results of consumers' acceptance of prebiotic burgers are summarized in **Table 5**. Despite the difference observed in the determination of instrumental color, there was no difference in the scores of the attribute "color" among treatments ($P > 0.05$). In addition, the addition of 3–12% inulin did not impair the "aroma" and "flavor" attributes scores of the burgers. However, the addition of 12% inulin caused a significant decrease in the "texture" attribute scores compared to the control. This depreciation of the texture was probably responsible for lowering the "overall liking" attribute scores of F12. This result can be attributed to the long length of the inulin chain and its high degree of polymerization (Niness, 1999; Wada et al., 2005). This fact makes inulin less soluble and more viscous, which can negatively affect the texture of reformulated products when added in high levels (Lopez-Lopez et al., 2010). A similar result was noticed by other authors (García et al., 2006; Álvarez and Barbut, 2013; Felisberto et al., 2015) who reported that the addition of levels above 5% of inulin increased the hardness of meat products.

In summary, the results of Experiment 1 demonstrated that the addition of up to 9% inulin did not affect consumers' acceptance and improved the yield and shrinkage of the burgers. Thus, the 9% inulin addition level was chosen for the Experiment 2, in which, besides to enrich the burgers with prebiotic fibers, a sodium reformulation was performed.

Experiment 2

The results of consumers' acceptance of prebiotic and low-sodium burgers are shown in **Table 6**. The scores of the attributes of "color" and "aroma" were not affected by sodium reformulation ($P > 0.05$). C_{KCl} had lower scores than C_{NaCl} in the attributes of "flavor," "texture," and "overall liking," demonstrating that the replacement of 60% of NaCl by KCl impaired the sensory quality of the burgers. These results can be attributed mainly to the bitter and astringent taste conferred by KCl when used in high levels as demonstrated by other studies (Dos Santos et al., 2014, 2015; Santos Alves et al., 2017; Da Silva et al., 2020; Zhang et al., 2020). The MG and LS samples had scores similar ($P > 0.05$) to C_{NaCl} in all sensory attributes evaluated. This result demonstrated that the isolated use of MG or LS was able to suppress the sensory defects caused by KCl. Moreover, MG+LS samples presented higher "liking" scores than C_{NaCl}. This outcome demonstrated that MG and LS had a synergistic effect in improving the sensory quality of low-sodium burgers.

CONCLUSION

The results of this study indicated that burgers of high technological and sensory quality can be produced by replacing 60% NaCl with KCl and using 9% inulin, 0.2% monosodium glutamate and 0.1% liquid smoke. However, further studies are needed to determine the influence of this reformulation on the shelf life of the burgers.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Human Research Ethics Committee of the Federal University of Santa Maria. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

BdS: conceptualization, investigation, and writing—original draft. AC: validation, visualization, and writing—review and editing. PC: conceptualization, supervision, project administration, funding acquisition, and writing—original draft. All authors contributed to the article and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.