Physical and sensory properties of low-salt phosphate-free frankfurters composed with various ingredients

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Abstract

The physical properties and sensory attributes of phosphate-free frankfurters were examined using the response surface methodology by varying the amounts of five compositional variables: salt, modified tapioca starch-, sodium citrate (NaC)- and wheat bran and fat in the batter. Altogether, 20 different types of frankfurters were prepared. When the frankfurters were made without phosphate, additional non-meat ingredients were needed at salt contents of less than 1.5%. Modified tapioca starch and sodium citrate decreased frying loss, with the former also improving water and fat binding.

Introduction

Due to the role of sodium in the development of hypertension in sodium-sensitive individuals, public health and regulatory authorities have recommended a reduced dietary intake of sodium chloride (Law, Frost & Wald, 1991a, b; Tuomilehto et al., 2001). Some contradictory opinions on the effect of sodium have also been presented (Graudal, Gall & Garred, 1998). Furthermore the presence of excessive amounts of phosphate in the diet may influence calcium, iron and magnesium balances in the human body and may consequently increase the risk of bone diseases (Shahidi & Synowiecki, 1997; Kärkkäinen, 1998).

In meat products, salt (NaCl) contributes to water and fat binding by expanding the filament lattice of myofibrils (Offer & Knight, review 1988) and by partially solubilizing the myofibrillar proteins (Hamm, review 1972). Salt reduction in most products will have an adverse effect on water and fat binding, thus impairing texture and increasing cooking loss (Girard, Culioli, Maillard, Denoyer &Touraille,1990). According to Sofos (1983a), a salt content in the range of 2.0-2.5% is necessary for the manufacture of commercial frankfurters without added phosphates and in the absence of any other ingredients that might supplement the effects of sodium chloride. In Finland, the salt content of cooked sausages with added phosphate is on average 1.7%. The goal is to continue decreasing salt content while simultaneously the demand for meat products made without added phosphate is increasing. Thus for further reductions in NaCl level, additional experiments with good binding quality lean meat, high pH values and the use of other components (e.g. proteins, gums, other salts, phosphates) is needed.

An acceptable low-sodium product without added phosphate can be achieved by increasing the amount of meat proteins or by decreasing the amount of added water. Because salt content in aqueous phase determines the effects of salt on water binding and gelling, a reduction in fat content will increase the need for more salt to reach the same level of water binding (Puolanne & Ruusunen 1983).

Numerous additives, e.g. sodium citrate, and ingredients have been used in phosphate-free meat products to enhance their water-binding capacity. Isolated soy protein is used for moisture and fat binding, emulsifying, and as an emulsion-stabilizing agent in finely comminuted meat products (Rhee, 1994). Sodium caseinate, soy protein isolate, whey protein concentrate or wheat germ flour can increase cooking yield of frankfurters (Atughonu, Zayas, Herald & Harbers, 1998). The high cooking yield with addition of non-meat ingredients is speculated to be due to an increasing pH effect, resulting in a higher water binding and gelling capacity during heat treatment. Mittal & Usborne (1985) reported such an effect with increased pH on meat batters with the addition of milk and soy proteins. Carrageenans have also been used in comminuted meat products to improve stability and texture, especially in low-fat products (Trius, 1994).

The chopping time and final batter temperature of the comminuted product have a significant effect on the stability of meat batter. Lean meat must be comminuted sufficiently to develop good binding properties. The batter has to be chopped long enough that the fat particles are well dispersed but not so long that the adipose cells are damaged and melted. Therefore, lean meat is usually chopped well before the fat is added (Ambrosiadis & Klettner, 1981). Moreover, if the temperature rise during chopping is excessively high, the fat may start to melt and separate, which would also weaken the formation of the myofibrillar protein network in which the fat and water are to be immobilized. According to Puolanne, Ruusunen & Kukkonen (1983), the temperature of phosphate-free batter should not exceed 16^{o}C, and according to Ambrosiadis and Wirth (1984) 12^{o}C. The temperature of batter made with phosphate should not exceed 20^{o}C and 18^{o}C, respectively.

This study is part of a project aimed at a reduction in sodium content of meat products. The effects of modified tapioca starch, sodium citrate (NaC) and wheat bran content as well as fat level separately and in combination on the physical properties and sensory characteristics of low-salt phosphate-free frankfurter were investigated.

Materials and preparation of sausages

The basic formulations used for frankfurters are presented in Table 1. All frankfurters were made without added phosphate. Meat batter preparation was performed with a chopper. Chopping was continued until the batter reached an endpoint temperature of 12^{o}C. Batters were stuffed into sheep casing (diameter 21-23 mm) and then formed into 15-cm links. The sausages were smoked and cooked in a smoking chamber until the core temperature reached 72^{o}C. After heat processing, the frankfurters were cooled in a cold water shower, vacuum-packed and stored at 2^{o}C.

The Response Surface methodology was used to study the effect of five compositional variables. Three levels of salt, modified tapioca starch, sodium citrate and wheat bran, and two levels of fat content were analysed in 20 combinations (Table 2).

Methods

pH value

The pH values of the sausage batters and frankfurters were measured directly with a Xerolyte electrode (Ingold Xerolyt LoT406-M6, Inlab 427, Mettler Toledo GmbH, Germany).

Frying loss

Three frankfurters were fried at the same time in an electric grill (Bistro Fix, Turku, Finland) for 2 min 30 s at 150 ^{o}C. The frankfurters were weighed before heating and 5 min after heating. Frying loss was calculated as a weight difference between the heated and the unheated weight (%).

Chemical analysis

Moisture content was determined by drying the sample at 104ºC for 16 h. Protein content was determined by the Kjeldahl method (NMKL, 1976). Moisture, protein and fat content were analysed from frankfurters numbered 1, 3, 9 and 11. NaCl concentration was determined by analysing chloride-ion content (Corning 926 Chloride Analyser, Corning Medical and Scientific Corning Limited, England). Sodium content was analysed with an Na-selective electrode (Ross™ sodium electrode, Orion Research Inc.). The Na-selective electrode method was a modification of Averill's (1983) and Kühne's (1988) methods (Kivikari, 1996).

Statistical analyses and modelling

The samples were prepared according to the recipes controlled by a statistical experimental design. The experimental plan was a half replicate of 2^5 factorial design with four repetitions in the center comprising 20 trials in total. The compositional model variables were salt, modified tapioca starch, sodium citrate, wheat bran and fat content. The fat content was categorical variable having only two experimental levels. Respectively, the response variables were batter pH, sausage pH, frying loss, sodium content, as well as sensory variables water and fat binding, firmness, saltiness, juiciness and flavour intensity. The experimental levels of the independent variables have been presented in Table 2. Due to the categorical nature of the fat content the repetitions consisted of two similar trials at both fat contents. In addition to the computed response surface models, the direct correlations between the dependent and independent variables were calculated.

All the computational work, including the graphical presentations of the response surface models, was performed using a Statistica for Windows software package (version 5.5, edition 99, Statsoft, Inc., Tulsa, OK, USA).

Sensory evaluation

Water and fat binding on the cut surface of cold frankfurters were evaluated using five-point scale: 5=very strong water and fat binding, 4= strong water and fat binding, 3=slightly weakened water and fat binding, a little dull, 2= weakened water and fat binding, dull, 1=weak water and fat binding, broken structure. A five-member panel evaluated the frankfurters twice, thus producing 10 evaluations per each 20 trials. However, only the grand mean of those 10 evaluations was the input to each trial in the computation of the response surface models and the correlations. Consequently, the number of the trials in the calculations of the experimental block has been 20. All panelists were specialists in the sensory analysis of sausages, particularly in evaluating the technological properties of sausages.

Firmness, saltiness, juiciness and flavour intensity of hot frankfurters were evaluated by a trained panel (N=10) with proven skills using descriptive analysis (Lawless & Heymann 1998). Attribute intensities were rated on 10-unit graphical intensity scales, which were anchored from their both ends (Table 3). The samples were presented to the panelists with three-digit codes and in random order, and water was provided for rinsing mouth between the samples. The samples were analysed in two sensory replicates, now producing 20 evaluations per each 20 trials. As above only the grand mean of those 20 evaluations was used as the final data of each trial in the calculations of the experimental block.

Results and discussion

Chemical analysis

The moisture content of frankfurters no. 1, 3, 9 and 11 was 66.5%, 63.5%, 66.7% and 64.3%, the fat content 15.9%, 20.3%, 15.3% and 20.1% and the protein content 14.7%, 13.7%, 15.1% and 13.4%, respectively. Frankfurters typically contain 2.0-2.5% salt (Whiting, 1988). Finnish frankfurters are usually made with phosphate and contain 1.7% salt. In this study, the added salt content of sausages ranged from 1.1% to 1.6%, and the analysed salt content from 1.14% to 1.73%. Sodium content ranged from 0.51 to 0.83 g Na/100 g. Besides with salt (r=0.834, p=0.000), sodium citrate (r=0.381, p=0.098) increased the sodium content of sausages (Table 4).

Physical analysis

The pH value of batters ranged from 5.73 to 5.89. The pH of frankfurters increased during heat processing. For cooked frankfurters, the pH ranged from 6.01 to 6.13. Sodium citrate increased the pH value of batters (r=0.560, p=0.010), and salt decreased the pH value of cooked frankfurters (r=-0.685, p=0.001) (Table 4). Puolanne, Ruusunen & Vainionpää (2001) have also shown that salt does decrease the pH of cooked sausages.

Frying loss

Salt (r=-0.389, p=0.090) and modified tapioca starch (r=-0.436, p=0.055) decreased frying loss the most (Table 4). The latter decreased frying loss at a fat content of both 15% and 20% (Figures 1a and b). The use of modified tapioca starch decreased frying loss especially in low-salt frankfurters. Sodium citrate also reduced frying loss (Figures 2a and b), with the effect being more marked in low-salt sausages than in high-salt ones. The frying loss was larger in low-salt frankfurters with 20% (Figure 2b) fat than in those with 15% fat (Figure 2a). Modified tapioca starch and sodium citrate decreased the frying loss in low-salt frankfurters. The optimum amounts were 2% and 0.5%, respectively.

Sensory analysis

Water and fat binding

Water and fat binding capacities of the cut surfaces of cold frankfurters were evaluated by sensory evaluation. Both salt (r=0.491, p=0.028) and modified tapioca starch (r=0.491, p=0.028) improved water and fat binding (Table 4). The latter also improved water and fat binding of low-salt frankfurters (Figures 3a and b). The effect was more marked in frankfurters with 20% fat (Figure 3b) than in those with 15% fat (Figure 3a).

For further reductions in NaCl content, the addition of extra lean meat with appropriate pH values and the use of other salts as sodium chloride and phosphates are needed. Whiting (1984) has shown that levels of 1.5-2.5% NaCl are needed to produce acceptable emulsion-type products, whereas salt levels of 1.0-1.5% may result in unstable emulsions or batters. In our study, soy protein isolate was used in every formulation. According to Rhee (1994), isolated soy protein improves moisture and fat binding in finely comminuted meat products.

Firmness and juiciness

As expected salt increased the firmness and juiciness of sausages (Table 4). Moreover, modified tapioca starch will increase the firmness of sausages (Figures 4a and b). Similar results have been obtained by other researchers. Matulis, McKeith, Sutherland & Brewer (1995) showed that salt increases hardness and juiciness of sausages. Sofos (1983b) manufactured frankfurters with beef-pork mixtures using commercial procedures and varying levels (1.0-2.5%) of NaCl. The author pointed out that a reduction in salt content of more than 20% (to less than 2.0% salt) resulted in frankfurters of less firm texture. Hand, Hollingsworth, Calkins & Mandigo, (1987) also reported that low-fat frankfurters containing 1.5% salt had a softer texture than those containing 2.0% or 2.5% salt.

Puolanne & Ruusunen (1983) have previously shown that the lowest salt content for acceptable texture in finely comminuted sausages with added phosphate is 1.5%. In this study was shown that in phosphate-free frankfurters a salt content of 1.5% is also critical.

Saltiness and flavour intensity

Wheat bran (Figure 6) and sodium citrate (Figure 7) enhanced perceived saltiness in frankfurters more than modified tapioca starch (Figure 5) but only at salt concentrations of less than 1.4%. The sodium citrate used contained 23.5% Na. Therefore, the addition of sodium citrate also increases the sodium content of the sausage. Salt is usually reported to enhance the total flavour intensity of meat products (Sofos, 1983b; Matulis, McKeith, Sutherland & Brewer 1995). This was also seen in our study. The variables studied affected saltiness and flavour intensity similarly (Table 5).

Fat and salt together contribute to many of the sensory characteristic of cooked sausages. Fat content had no effect on saltiness (Tables 4 and 5), although in earlier studies the fat content of cooked sausages has been reported to affect the perceived saltiness in different ways depending on the composition of the formulation (Hammer, 1981; Matulis, McKeith & Brewer, 1994; Ruusunen, Simolin & Puolanne, 2001. In these studies fat content ranged from (5) 8 to (35) 28%, while fat content in our study was either 15% or 20%. The small difference in fat content between our frankfurters may be the reason why no difference was found.

Conclusions

When frankfurters are made without phosphate, non-meat ingredients are needed at salt concentrations of less than 1.5%. Modified tapioca starch and sodium citrate decrease frying loss. Modified tapioca starch also improves water and fat binding.

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Table 1. Basic formulation of frankfurters with fat content of 15% or 20%.

	Fat content 15%	Fat content 20%
Beef, 22% fat (%)	20.00	20.00
Pork, 12% fat (%)	40.00	30.00
Pork fat, 89% fat (%)	-	10.00
Pork skin (%)	6.00	6.00
Soy protein isolate (%)	2.00	2.00
Spices and glucose (%)	0.52	0.52
Ascorbic acid (%)	0.06	0.06
Sodium nitrite (%)	0.012	0.012
Water, ice (%)	28.80	28.80
Test ingredients + maltodextrin (%)	2.50	2.50
Total (%)	100.00	100.00

Table 2. Levels of test ingredients (%) added to frankfurters.

Frankfurter number	Salt %	Fat %	Modified tapioca starch %	Wheat bran %	Sodium citrate %
1	1.10	15	0.00	0.00	.50
2	1.60	15	0.00	0.00	0.00
3	1.10	20	0.00	0.00	0.00
4	1.60	20	0.00	0.00	.50
5	1.10	15	2.00	0.00	0.00
6	1.60	15	2.00	0.00	.50
7	1.10	20	2.00	0.00	.50
8	1.60	20	2.00	0.00	0.00
9	1.10	15	0.00	1.00	0.00
10	1.60	15	0.00	1.00	.50
11	1.10	20	0.00	1.00	.50
12	1.60	20	0.00	1.00	0.00
13	1.10	15	2.00	1.00	.50
14	1.60	15	2.00	1.00	0.00
15	1.10	20	2.00	1.00	0.00
16	1.60	20	2.00	1.00	.50
*	*	*	*	*	*
17	1.35	15	1.00	.50	.25
18	1.35	20	1.00	.50	.25
19	1.35	15	1.00	.50	.25
20	1.35	20	1.00	.50	.25

Table 3. Anchors for attributes used to characterize the properties of hot frankfurters.

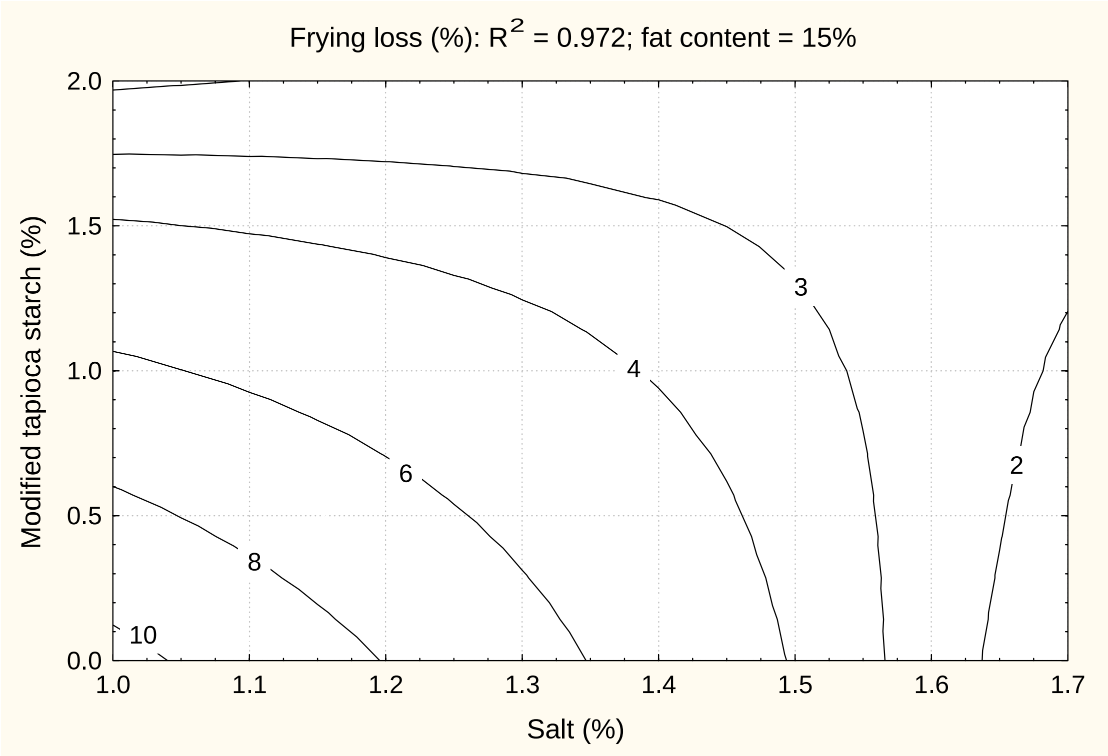
	0=	10=
Firmness	Soft	Firm
Saltiness	Not at all	Extremely salty
Juiciness	dry	juicy
Flavour intensity	weak flavour	strong flavour

Table 4. Correlation coefficients between the compositional variables and the analysed chemical, physical and sensory properties of frankfurters.

Variable/ Property	Salt	Fat	Modified tapioca starch	Wheat bran	Sodium citrate
Batter pH	-0.305	0.079	0.030	-0.049	0.560
	p=0.191	p=0.740	p=0.902	p=0.837	p=0.010
Sausage pH	-0.685	0.048	0.013	-0.202	0.363
	p=0.001	p=0.841	p=0.955	p=0.394	p=0.116
Frying loss	-0.389	0.057	-0.436	-0.205	-0.318
	p=0.090	p=0.811	p=0.055	p=0.386	p=0.172
Na (mg/100)	0.834	-0.066	-0.099	-0.072	0.381
	p=0.000	p=0.782	p=0.679	p=0.763	p=0.098
NaCl	0.981	-0.041	-0.089	-0.056	-0.062
	p=0.000	p=0.864	p=0.710	p=0.813	p=0.796
Water and fat binding	0.491	0.098	0.491	0.164	0.273
	p=0.028	p=0.682	p=0.028	p=0.491	p=0.245
Firmness	0.627	0.075	0.367	0.153	0.321
	p=0.003	p=0.753	p=0.111	p=0.520	p=0.167
Saltiness	0.731	0.016	0.055	0.128	0.128
	p=0.000	p=0.945	p=0.818	p=0.591	p=0.591
Juiciness	0.387	0.186	0.089	-0.288	0.288
	p=0.092	p=0.431	p=0.708	p=0.219	p=0.219
Flavour intensity	0.655	-0.167	0.281	0.135	0.177
	p=0.002	p=0.481	p=0.231	p=0.570	p=0.456

Table 5. Statistical significance of each variable in Response Surface models.

Property/Variable	Batter pH	Sausage pH	Frying Loss	Na mg/100	Water and fat binding	Firmness	Saltiness	Juiciness	Flavour intensity
R^2	0.950	0.926	0.972	0.996	0.932	0.965	0.987	0.859	0.986
	p	p	P	p	p	p	p	p	p
Fat	0.014	0.126	0.130	0.053	1.000	0.045	0.196	0.992	0.612
Salt	0.315	0.423	0.002	0.000	0.014	0.005	0.000	0.068	0.000
Tapioca starch	0.020	0.403	0.003	0.002	0.026	0.009	0.005	0.171	0.004
Wheat bran	0.042	0.175	0.051	0.007	0.661	0.209	0.005	0.307	0.011
Sodium citrate	0.806	0.375	0.007	0.005	0.136	0.380	0.002	0.046	0.002
Fat*salt	0.019	0.168	0.432	0.049	0.697	0.101	0.190	0.805	0.869
Fat*tapioca starch	0.208	0.423	0.477	0.052	0.277	0.122	0.131	0.960	0.190
Salt*tapioca starch	0.022	0.423	0.011	0.002	0.043	0.020	0.015	0.227	0.016
Fat * wheat bran	0.934	0.338	0.033	0.233	0.104	0.178	0.276	0.138	0.085
Salt * wheat bran	0.043	0.106	0.138	0.007	0.697	0.460	0.009	0.372	0.021
Tapioca starch* wheat bran	0.570	0.527	0.109	0.984	0.277	0.549	0.019	0.882	0.012
Fat*sodium citrate	0.386	0.133	0.182	0.018	0.697	0.460	0.276	0.659	0.430
Salt * sodium citrate	0.208	0.781	0.021	0.112	0.277	0.760	0.004	0.068	0.003
Tapioca starch *sodium citrate	0.471	0.338	0.022	0.007	0.277	0.101	0.007	0.329	0.021
Wheat bran * sodium citrate	0.471	0.781	0.330	0.031	0.697	0.147	1.000	0.882	0.430



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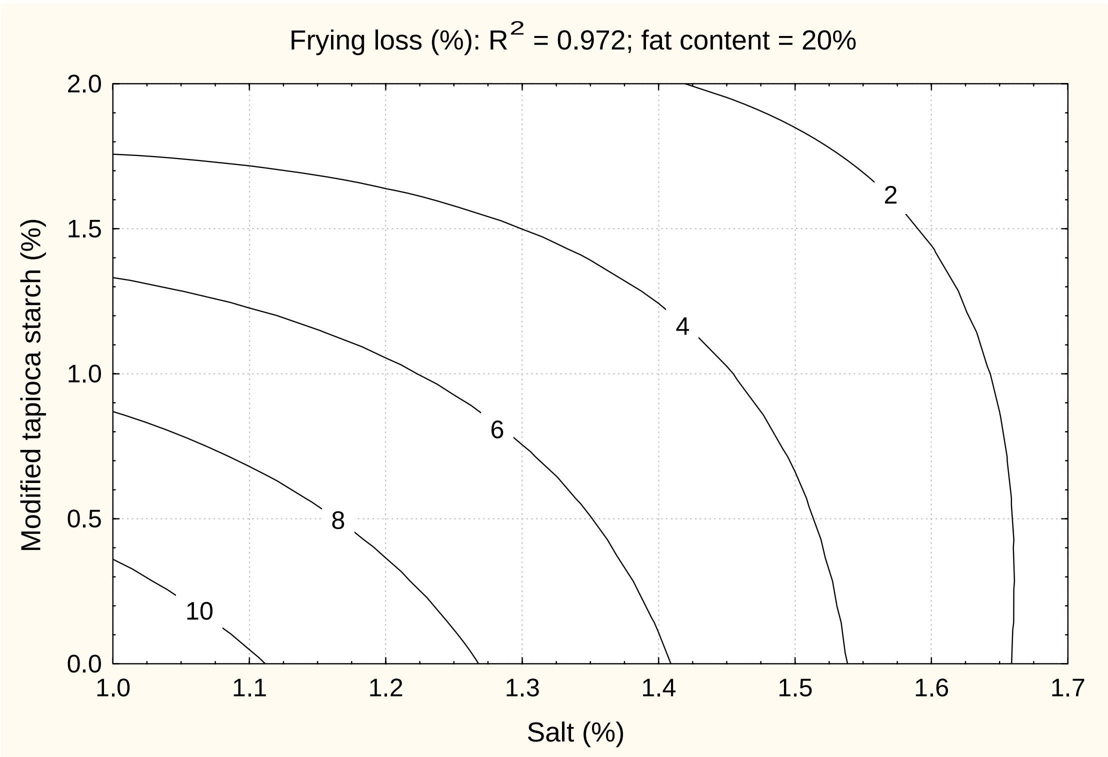

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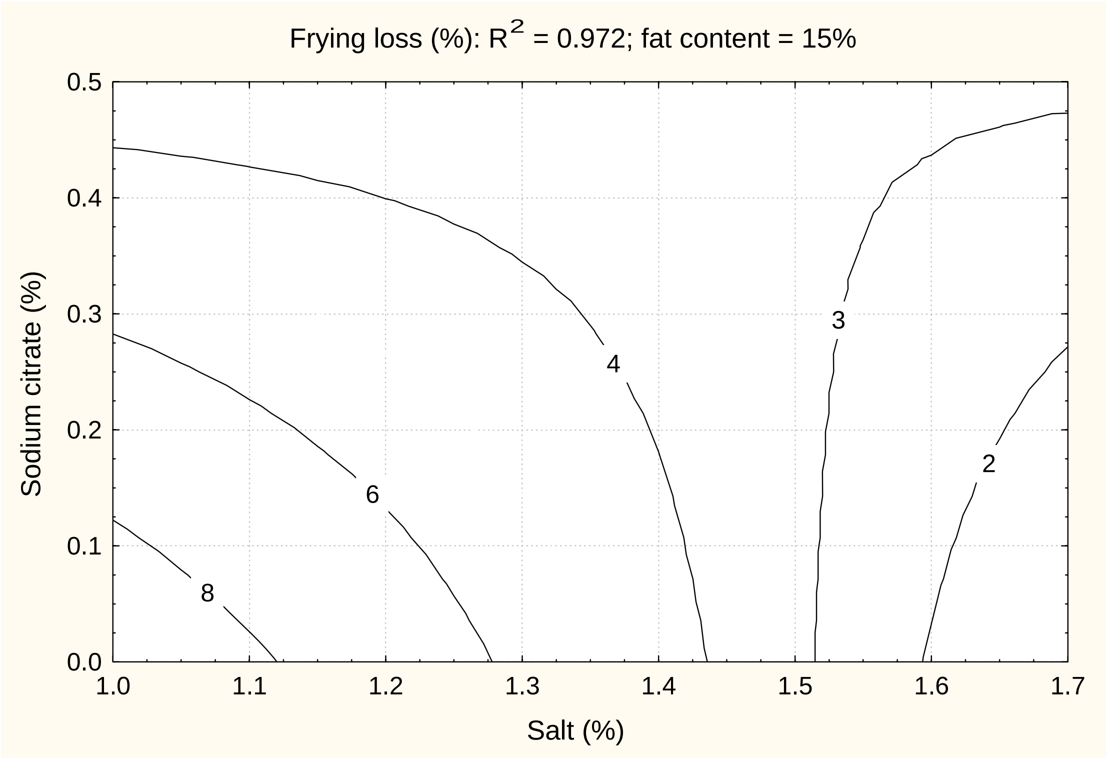
Figures 1a and b. Frying loss of frankfurters by salt and modified tapioca starch content; a, fat content 15%, b, fat content 20%.



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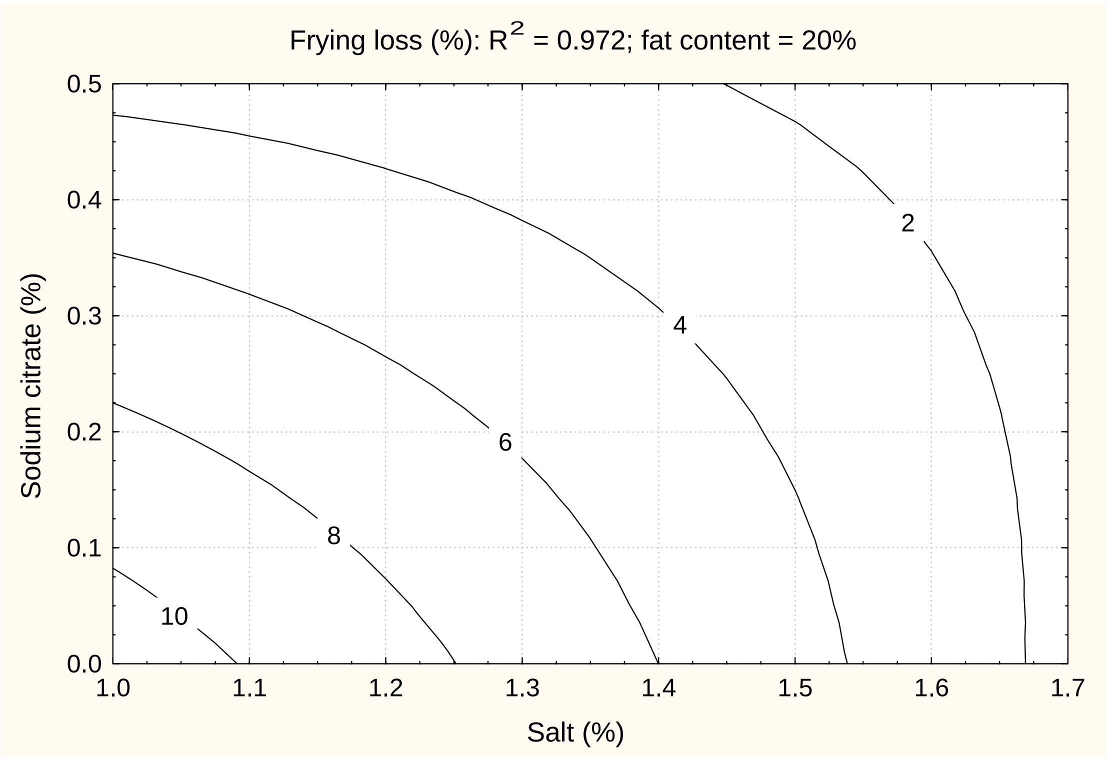
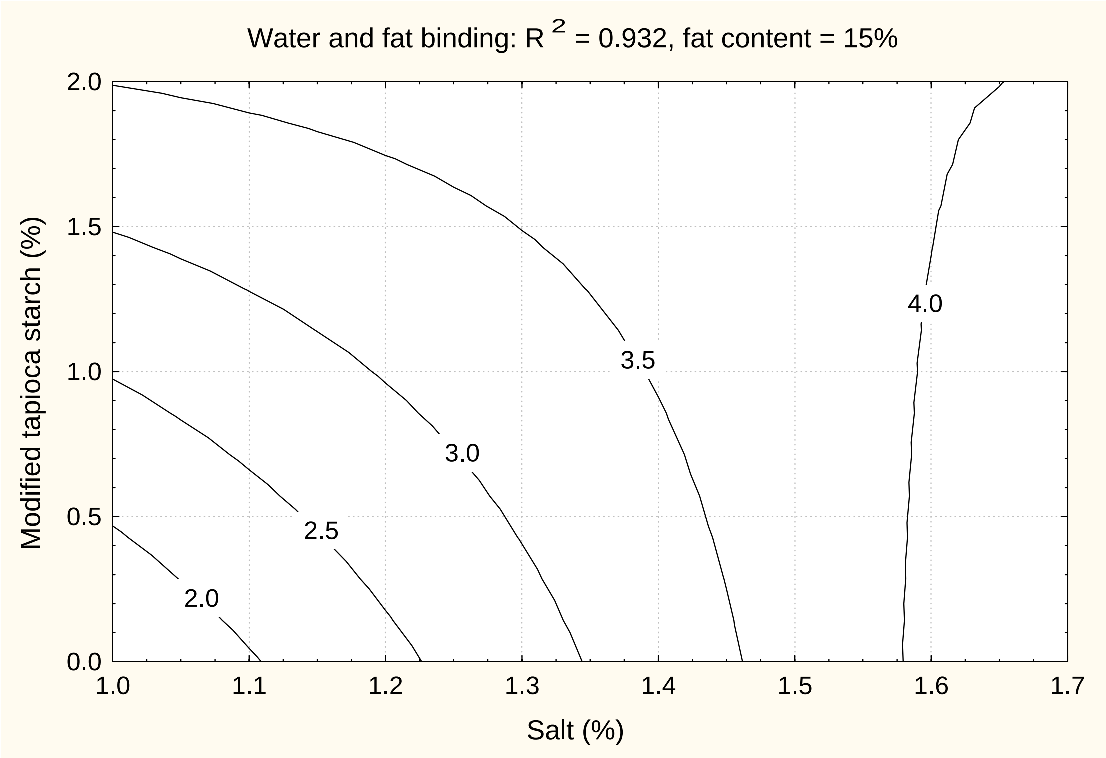
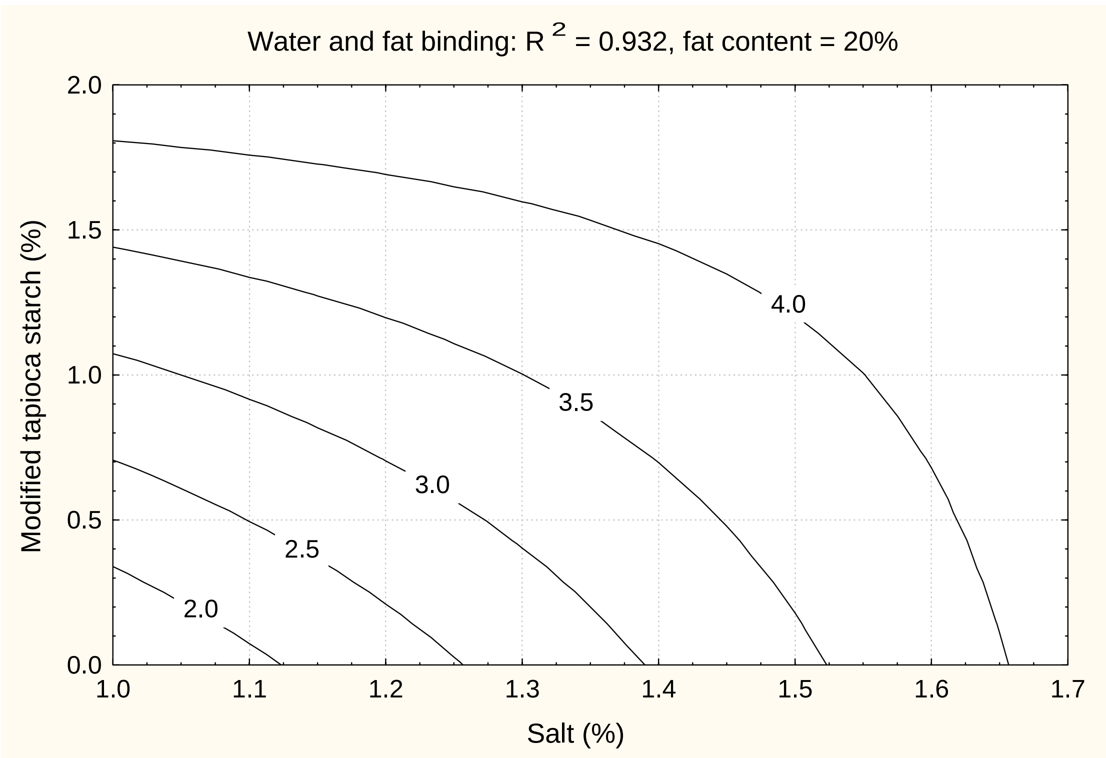


b)

Figures 2a and b. Frying loss of frankfurters by salt and sodium citrate content; a, fat content 15%, b, fat content 20%.

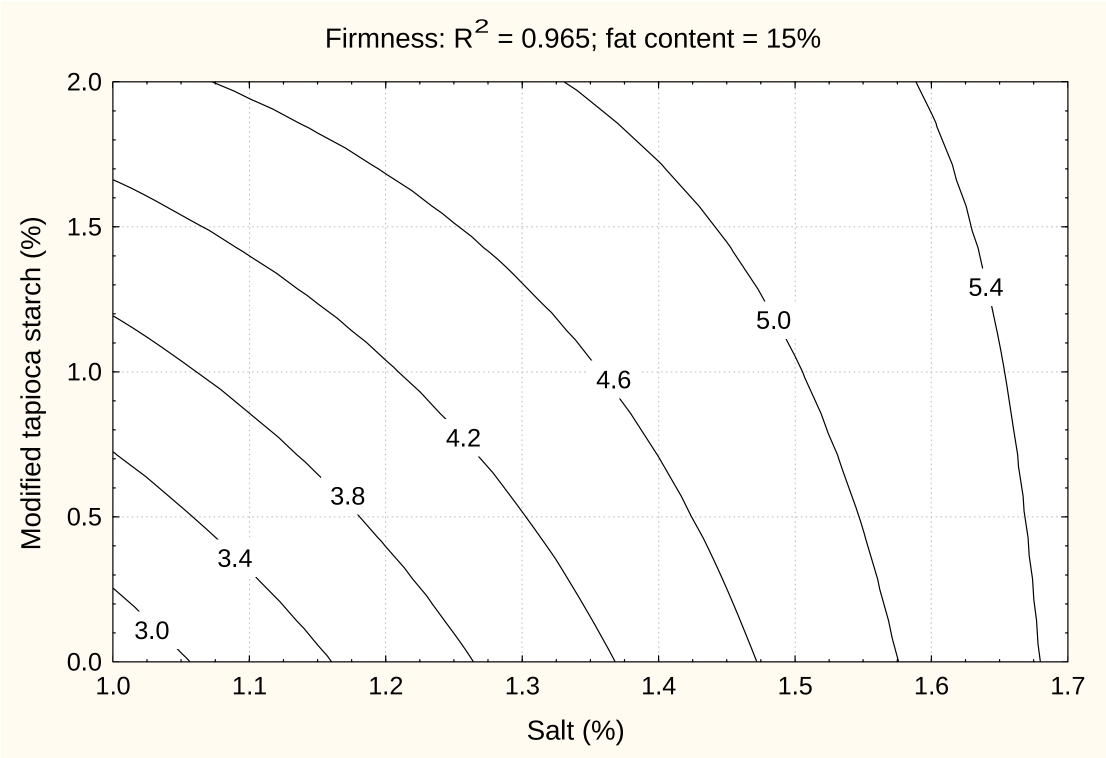


a)

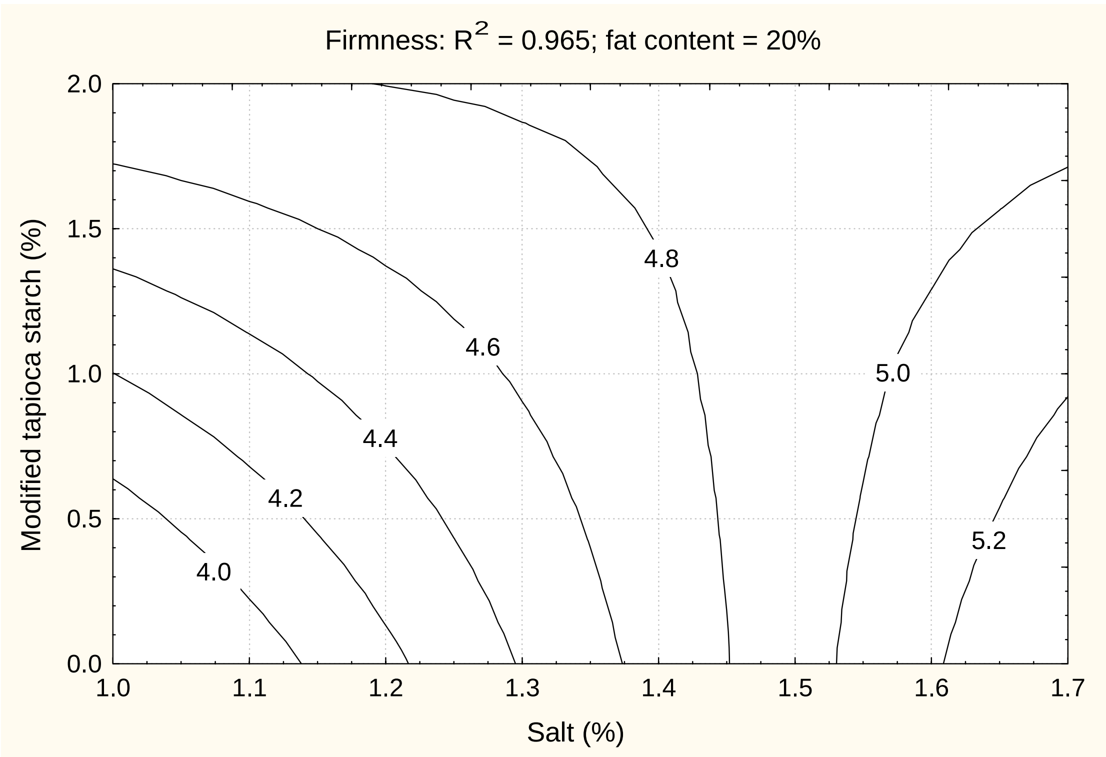


b)

Figures 3a and b. Water and fat binding of frankfurters by salt and modified tapioca starch content; a, fat content 15%, b, fat content 20%.



a)



b)

Figures 4a and b. Firmness of frankfurters by salt and modified tapioca starch content; a, fat content 15%, b, fat content 20%.

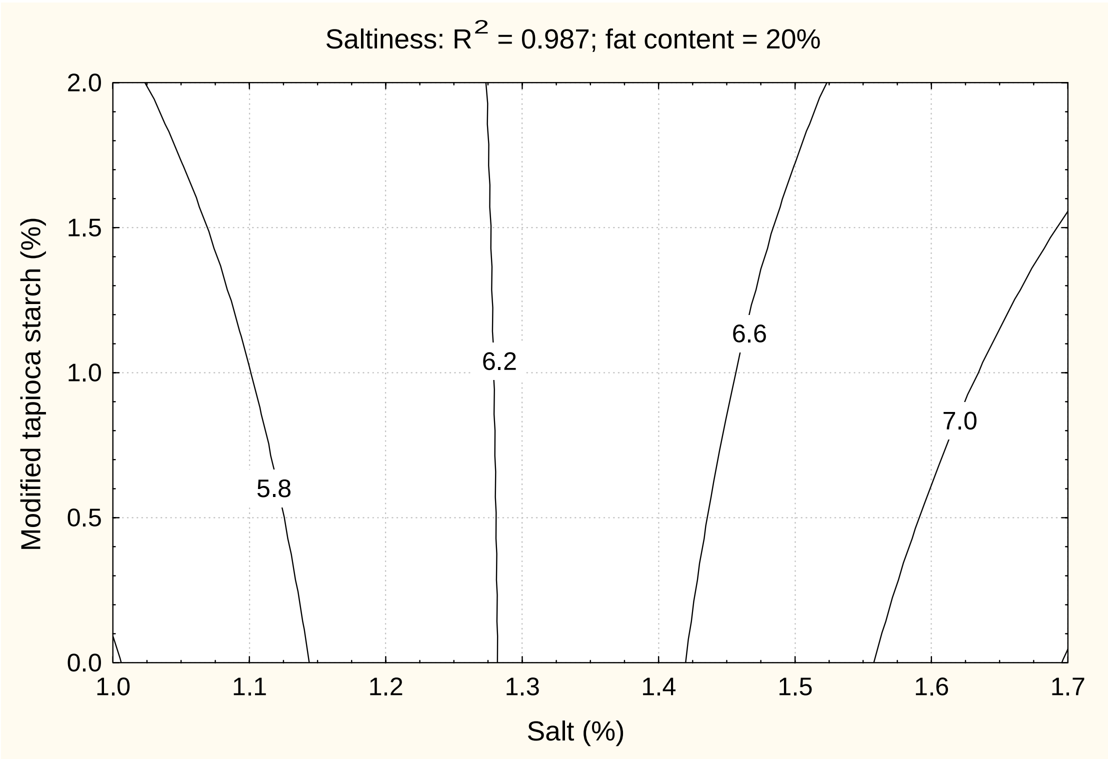


Figure 5. Saltiness of frankfurters by salt and modified tapioca starch content.

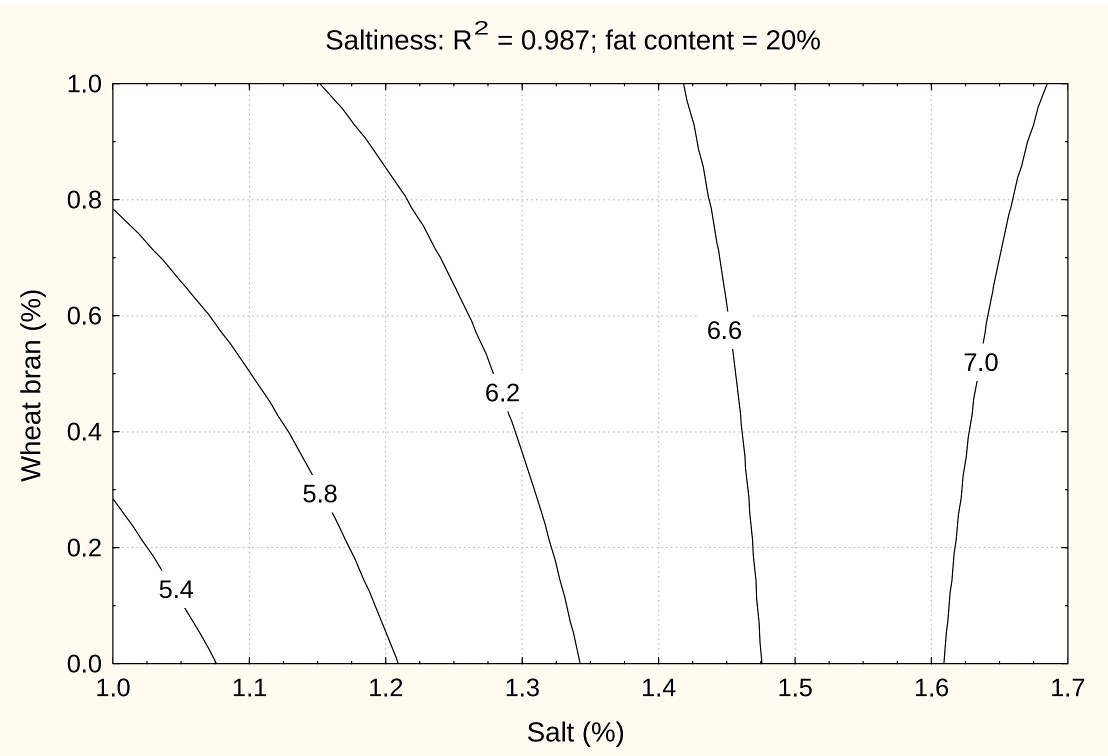


Figure 6. Saltiness of frankfurters by salt and wheat bran content.

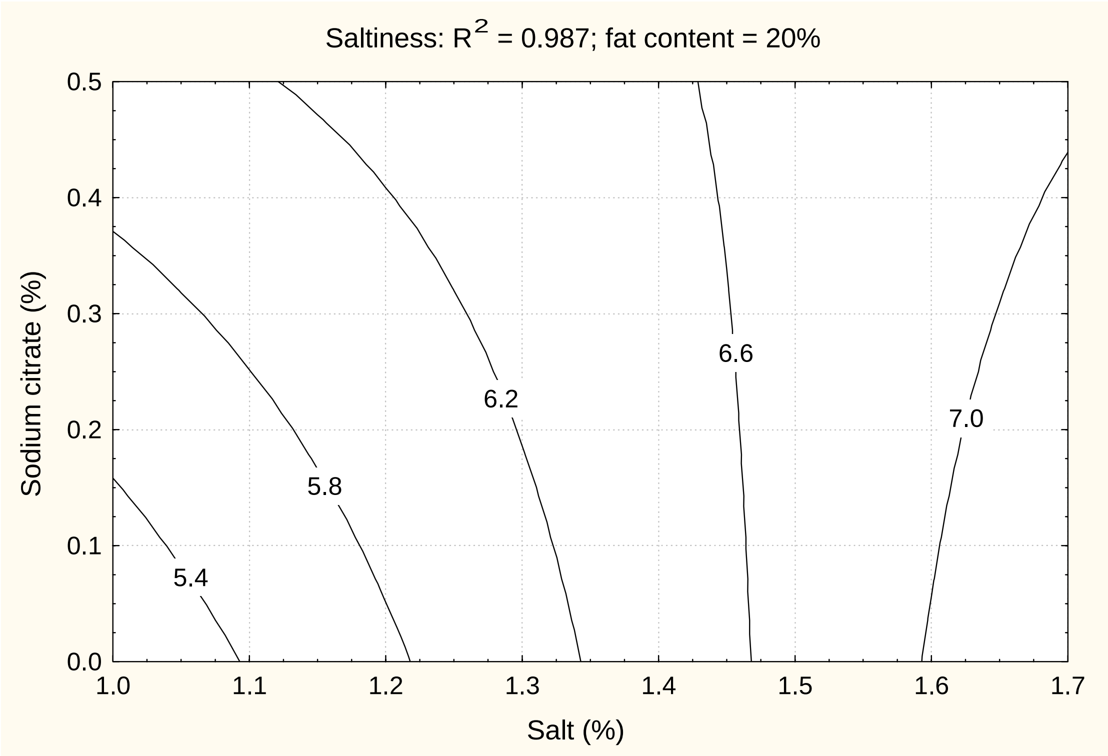


Figure 7. Saltiness of frankfurters by salt and sodium citrate content.