Justifying the Possibility to Reduce Fat and Salt Content in Raw Smoked Sausages

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Abstract: The study looks for the ways to decrease the content of salt and fat in raw smoked sausages. Usage of animal fat and salt in raw smoked sausage production process is crucial for ensuring the high quality and safety standard of the final product. On the other hand, food safety considerations in recent decades have established a steady trend to decrease animal fat and salt consumption. All this brings about a certain controversy between technological, hygienic and economic requirements to ready-to-eat raw smoked sausages. The research addresses the viability of decreasing fat and salt content in the raw smoked sausage ground meat and final product to maintain the traditional (expected) customer appeal and ensured microbiological safety level without disrupting the economic feasibility of production. The conducted research and experimental data analysis have identified the impact of low salt content in formulations of the sausages featuring the lowest correlation between lean meat and fatty tissue. The ground meat with salt content not exceeding 1.5% of the weight of the unsalted primary products cannot be accepted for raw smoked sausage production as incapable of ensuring both the traditional organoleptic features and sufficient product yield. It is possible to decrease the fat content in raw smoked sausages by applying a greater correlation of lean and fat-containing ingredients provided that the ground meat salt content is at least 2.5% or higher. Forecasting of the changes of the ground meat overall chemical composition and its physical and chemical properties (above all the moisture content and water activity) when designing technologies to make new raw smoked sausage sorts and improve the existing ones facilitates control over the final products' composition and properties including the ensured safety level and reasonable economic performance.

Keywords: raw smoked sausages, salt, beef, pork fat, composition, drying/ripening, water activity, pH, organoleptic properties.

Introduction

The recent decades have witnessed an emerging tendency to enhance nutrition safety by decreasing animal fat and salt consumption [1]. The former is to a significant extent conditioned by the changing lifestyles and declining need for high-calorie foods among most age and professional groups of population. The limitations on excessive salt consumption are attributable to the high risk of cardiovascular diseases

caused by sodium chloride (mostly due to sodium ions). It is worth mentioning that the existing food safety recommendations (MR 2.3.0122-18) based on FAO/WHO requirements restrict daily salt consumption to 5 g [2], although the actual consumption is considerably higher.

In most countries meat products serve as the principal source of native animal proteins. On the other hand, primary and, consequently, ready-to-eat meat products, most notably sausages, are rich in fat. It is predetermined, first of all, by peculiar features of primary meat products conditioned by the meat source species, its nutritional status and applied fattening procedures, as well as the grading system [3]. Besides, fat content in final meat products also depends on the accepted product formulation. It must be mentioned that the traditional Russia-made sausage products feature fat-to-protein ratio varying within a broad range from 0.7/1 to 4.8/1. This can be illustrated by a well-known bologna-type sausage brand *Doctorskaya* (production standard GOST R 52196-2017), which was originally designated as a wholesome food, features a 1.5/1 fat-to-protein ratio while its formulation does not include such fatty tissues as pork fat or pork belly. The most popular traditional raw smoked sausages have the fat-to-protein ratio within the range of (1.5-2.5)/1 [4]. Decreasing the fat content in sausages contradicts to the established production procedures, organoleptic and economic requirements to processed products [5]. The Austrian meat and meat products quality guidelines stipulate that the fat content in the sausages marked as low-fat ones must be at least 30% lower than that of their traditional counterparts [6]. At the same time a well-known work [7] mentioned that the low-fat raw smoked sausages such as *Rindwurst* demonstrate an extremely limited number of consumers.

The conventional meat products making technologies are based on adding salt which constitutes from 1.5% to 3.5% of the total volume of the principal ingredients [8-10] thus becoming the 'weightiest' one among the additives used in meat products technology. There are several reasons for using salt. Firstly, salt is a popular food additive used to control taste, color and touch of the final products. Secondly, salt is traditionally used for foodstuffs preservation due to its featuring the highest water activity (a_w) reduction capacity as compared to other food additives [11] and, as mentioned above, given the larger amount of its involvement in foodstuff formulations. Certain authors argue that the minimum salt content in the traditional European raw smoked sausages must be at least 2.4–2.5%, estimating the optimum and maximum contents at 2.8–3.0% and 3.5% respectively [7,12]. The latter value is descriptive of Russia-made raw smoked sausages and has been maintained by their manufacturers over multiple decades. There is a number of ways to reduce sodium chloride in raw smoked sausage formulations. One of these implies full or partial substitution of sodium chloride with lactates or other (potassium and/or magnesium and/or calcium) chlorides [13,14]. Such substitution, however, results in deviation from the customary organoleptic properties, primarily the taste. Another adverse result of using salt substitutes is unfavorable change of the ground meat physical and chemical properties including, first of all, active acidity moving to the basic region thus increasing the ground meat unwanted water-binding capacity and worsening the starting conditions for lactic acid producing microorganisms [15].

Combination of the low water activity level and active acidity (pH) serves as the principal hurdle against unwanted bacteria growth during raw smoked sausage production. Whereas $a_w \leq 0.90$-0.91, usually together with a decreased pH level (≤5.0), is sufficient for production of semidry raw smoked sausage, making dry raw smoked sausages requires lowering the drying/ripening water activity level below 0.86–0.88 [16]. However excessive water activity reduction (below 0.80) produces an adverse impact on both the customer appeal (first of all by increasing the hardness of the sausage) and the economic parameters, such as the declining end product output and elongated production process [17].

Methods and materials

The research aimed at investigating the viability to lower fat and salt content in raw smoked sausages without decreasing the end product microbiological safety, customer appeal and economic parameters of its production.

The readiness of raw smoked sausages is traditionally estimated by achieving the limit (maximum) moisture percentage established by respective regulatory documents, such as national and interstate standards. The documents of this kind currently effective in Russia are National Standard GOST

R 55456-2013 *Smoked sausages. Specifications* and National Standard GOST 33708-2015 *Smoked and dried sausages. General specifications.* Both documents establish the threshold moisture amounts, GOST 55456-2013 setting forth requirements to individual kinds of sausage and GOST 33708-2015 specifying those for entire product groups (types). The national standard limits the maximum acceptable moisture content to the range between 25% and 36% for dry raw smoked sausages and 36–42% for semidry ones [18]. Such moisture values are conditioned by the general chemical composition of the ground meat: the lower values pertain to the sausages featuring higher fat-to-protein ratio, while the higher ones are descriptive of the sausages with smaller correlation of those two components.

In European and Northern American countries meat product quality and safety control procedures use alongside with or instead of the moisture value such parameter as moisture-to-protein ratio: MPR in the U.S. [19] or Q2 in Austria. Meanwhile there is also a tendency to use for the same purposes the water activity indicator (a_w) which is considered more informative by a number of experts both in Russia and abroad [1,19] as unlike MPR it also takes into account the presence of preserving agents, primarily salt.

The European dry sausage technologies typically require the water-to-protein ratio to be kept below 1.3 [20] which corresponds to the water activity level below 0.86, while in the U.S. it is maintained below 1.9 [21, 22] ($a_w < 0,88$). It must be mentioned that the sausages made of low-fat meat and featuring the identical salt content and water-to-protein ratio tend to demonstrate the maximum water activity level while in the sausages with high ground meat fat content this value is lower.

Thus any new formulation of a raw smoked sausage with predetermined chemical composition and properties should not be designed without taking into account the correlation of ground meat ingredients, primarily lean meat, fatty tissue and salt, as well as the moisture reduction level which ensures the end product microbiological safety by maintaining the maximum water activity level.

The examination of ground meat, prefabricated components and ready-to-eat sausages was performed using analytic, physical, chemical and organoleptic methods.

The changes of the model ground meat composition and water discharge and activity level were calculated with specially designed software based on material balance maintenance. The weight fractions of fat, salt and protein were calculated by conventional methods. The moisture content was measured thermogravimetrically with an A&D MX-50 moisture analyzer. The active acidity was evaluated by potentiometry using Hanna precision pH meter Model pH 213. The water activity was assessed under National Standard GOST ISO21807-2015 using an AVK-10 cryoscopic analyzer of *AVK* LLC production [23]. The water-holding capacity (WHC, %) of the raw-meat materials was measured by the Grau-Hamm filter paper press method in Volovinskaya-Kelman modification. The organoleptic evaluation of the ready-to-eat sausages was carried out under the GOST 9959-2015 nine-point grading scale.

Each of the tests was run with five replicates, the tests results being processed by methods of mathematical statistics using Microsoft Excel software.

Results

The research procedures included simulation modeling of raw smoked sausage model ground meat general chemical composition and properties' changes conditioned by moisture decrease during drying/ripening. The principal raw material was represented by prime beef with fat and connective tissues content not exceeding 3% and pork back fat. The physical and chemical properties of the raw-meat materials (*Table 1*) and its overall chemical composition (*Table 2*) were evaluated prior to commencing the tests.

The study chose for the baseline formulation that of *Sujuk* dry sausage whereof the ratio of lean meat (beef, lamb, buffalo meat, camel meat) to fat-containing one (beef, broadtail and/or hump fat) traditionally varies between 90% to 10% and 80% to 20% [24-26]. Thus sujuk is one of the leanest traditional sausages with the lowest fat content. The salt content within the testing framework was 1.5, 2.5 and 3.5 per cent of the weight of the unsalted raw materials (*Table 3*) which covers the entire range of salt content provided for by the currently used formulations of raw smoked and dry cured sausages. The separate usage of salt and sodium nitrite instead of the nitrated curing mixture required by the Customs Union Technical Regulations TR TS034/2013 was due to the need to maintain the adopted proportion of sodium nitrite in the principal raw materials.

TABLE 1.
The Physical and Chemical Properties of the Raw-meat Materials

Meat	pH	a_w	WHC, %:	
			to overall moisture content	to the test portion weight
Beef	5.32±0.05	0.9850±0.0013	71.37±0.85	53.92±0.61
Lard/pork fat	5.69±0.04	0.9846±0.0010	–	–

TABLE 2.
Overall Chemical Composition of the Raw-meat Materials

Meat	Weight fraction, %:			
	moisture	protein	fat	ash
Beef	76.00±0.30	21.11±0.15	1.78±0.12	1.11±0.06
Lard/pork fat	7.02±0.12	1.91±0.13	90.97±1.09	0.10±0.03

TABLE 3.
Formulations of Model Sausages' Ground Meat

	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3
Unsalted raw-meat materials,g per 1000 g									
Prime beef	900			850			800		
Backfat	100			150			200		
Spices and additives, g per 1000 g of the unsalted raw-meat materials									
Salt	35	25	15	35	25	15	35	25	15
Sugar	2								
Black pepper	1								
Caraway	0.5								
Garlic	20								
Sodium nitrite	0.1								

Figure 1 demonstrates the results of the simulation modeling of the ground meat water activity changes brought about by decreasing the moisture content during drying/ripening of the model sausages depending on correlation between the lean and fat-containing raw-meat materials and the amount of salt added to the ground meat. The maximum level adopted by dry raw smoked sausage making technologies is $a_w < 0.88$ as at such level *S. aureus* becomes incapable of generating toxins, while at $a_w < 0.86$ it loses its growth capacity.

Table 4 represents the weight content of moisture and salt, as well as the water-to-protein ratio and the output of the raw smoked sausage model samples, as the water activity achieves the threshold values of 0.88 and 0.86.

The national standards GOST R 55456-2013 and GOST 33708-2015 require the sodium nitrite content in ready-to-eat dry raw smoked sausages not to exceed 6% whereas the European technologies provide for a still lower value, namely the one not exceeding 4.5–5.0% [28, 29]. The salt content growth beyond 6% at the water activity level of 0.86 was registered at the proportion of salt added to the ground meat being 3.5% and beef-to-fat ratio being 90/10.

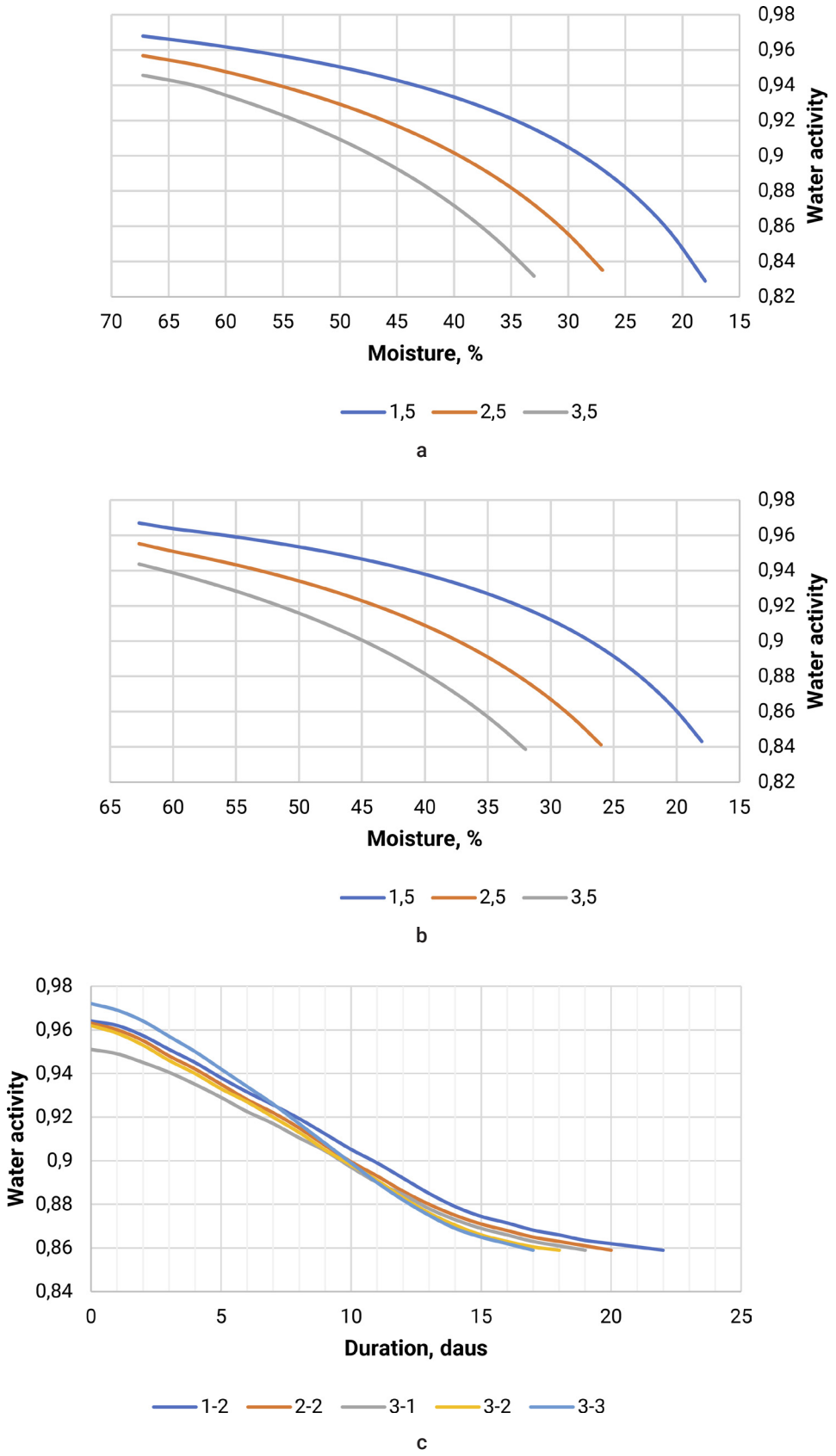

Figure 1. Water activity changes brought about by decreasing the model sausages' ground meat moisture content with the beef-to-fat ratio being: a – 90/10; b – 85/15; c – 80/20

Table 4.
Sausage Features Depending on the a_w Value and the Ground Meat Salt Content

Features	Formulation	Water activity in processed sausage					
		0.88			0.86		
		Ground meat salt content, %					
		1.5	2.5	3.5	1.5	2.5	3.5
Moisture weight content, %	90/10	24.7	34.6	42.0	21.5	30.7	37.8
	85/15	22.9	32.4	39.8	19.9	28.8	35.5
	80/20	21.5	30.7	37.6	18.6	27.1	33.7
Salt weight content, %	90/10	3.39	4.76	5.74	3.53	5.04	6.16
	85/15	3.15	4.48	5.44	3.27	4.72	5.83
	80/20	2.94	4.21	5.19	3.04	4.44	5.51
Protein-to-moisture correlation	90/10	0.48	0.96	1.35	0.58	0.80	1.13
	85/15	0.51	1.00	1.42	0.61	0.85	1.18
	80/20	0.54	1.07	1.49	0.64	0.89	1.25
Output, %	90/10	43.5	51.1	58.7	41.7	48.2	54.7
	85/15	46.8	54.3	62.0	45.0	51.5	57.8
	80/20	50.2	57.7	65.0	48.4	54.8	61.1

The weight content of moisture in dry raw smoked sausages must not exceed 36% as per GOST 33708-2015. In all the samples with the 3.5% ground meat salt content the weight content of moisture exceeds the standard level by 1.6–6.0% at the water activity level reaching 0.88.

All the model sausage samples' water-to-protein ratio at the water activity level of 0.86 is much lower than the standard values adopted abroad (1.3/1). It ranges from 1.25/1 in the samples with the beef-to-fat ratio of 80/20 and the maximum level of the ground meat salt content to 0.42/1 in the samples with the beef-to-fat ratio of 90/10 and the minimum ground meat salt content.

The largest ready-to-eat product output at the water activity level of 0.86 was achieved by the sample featuring the 80/20 (61.1%) beef-to-fat ratio and the 3.5% ground meat salt content while the lowest one was yielded by the sample with the 90/10 (43.5%) beef-to-fat ratio and the 1.5% ground meat salt content.

Discussion

The impact of ground meat salt on the model raw smoked sausages featuring various beef-to-fat ratio was estimated by means of a trial production of raw smoked sausages compliant with the Table 1 formulations ran on Saratov State Vavilov Agrarian University's *Pishchevik* training research and production facility. The raw meat mix was stuffed into 45-mm caliber artificial fibrous BDO permeable casing.

Five samples were selected for testing out of 9 sausage formulations which had undergone simulation modeling. The samples with 3.5% salt content and beef-to-fat ratio of 90/10 and 85/15 are prone to the salt content exceeding 6% if the water activity drops below 0.86 even to a minor extent which can happen during storage (*Table* 4). Samples with the salt content of 1.5 and beef-to-fat ratio of 90/10 and 85/15 demonstrate excessive weight loss and, therefore, an excessively low moisture to protein ratio (<0.62). Therefore it is the samples made by formulations 1-2, 2-2, 3-1, 3-2 and 3-3 (*Table 3*) which are subject to further research.

The slightly frozen raw-meat products were minced with a meat grinder with 3 mm grid hole size. Then the ground meat was mixed with the curing ingredients and stuffed into the casing with a handheld piston stuffer to form 150 g links tied with twine from both ends. Upon being tempered for two days at 2–4 °C the sausage was exposed to short term (12 hours) cold smoking at 18–22 °C followed by

drying/ripening at 18→15 °C and relative moisture of 85→75% up to the predetermined release level corresponding to the water activity achieving 0.86 (*Table 4*), the release being estimated by regular measuring the weight of the sausage links.

Figure 2 shows the water activity dynamics as the raw smoked sausage model samples are processed in sausage links.

It can be seen from the diagram that the water activity is dropping faster in the samples with a smaller beef-to-fat ratio and lower ground meat salt content. This is due to the better weight transfer in the ground meat with higher fat content and a greater-ground meat water-binding capacity demonstrated by the samples with the higher salt concentration as the presence of salt in ground meat increases the pH value [30]. The overall chemical composition, as well as chemical and physical properties of the model sausage samples are specified in Table 5.

The model sausages' fat-to-protein ratio is around 0.60/1 for formulation 1, around 1.17/1 for formulation 2 and around 1.26/1 for formulation 3. In order to achieve the water activity level of 0.86 as the formulation salt content drops from 3.5% to 1.5% it is required to decrease the sausage moisture approximately by a factor of 1.8 during the sausage production. Lowering of the original ground meat salt content entails a pH value decrease (*Table 5*) thus accelerating drying/ripening (*Figure 2*).

Figure 3 outlines the sensory profiles of the model sausage samples.

Analyzing the impact which the low salt content produces on the organoleptic properties of model

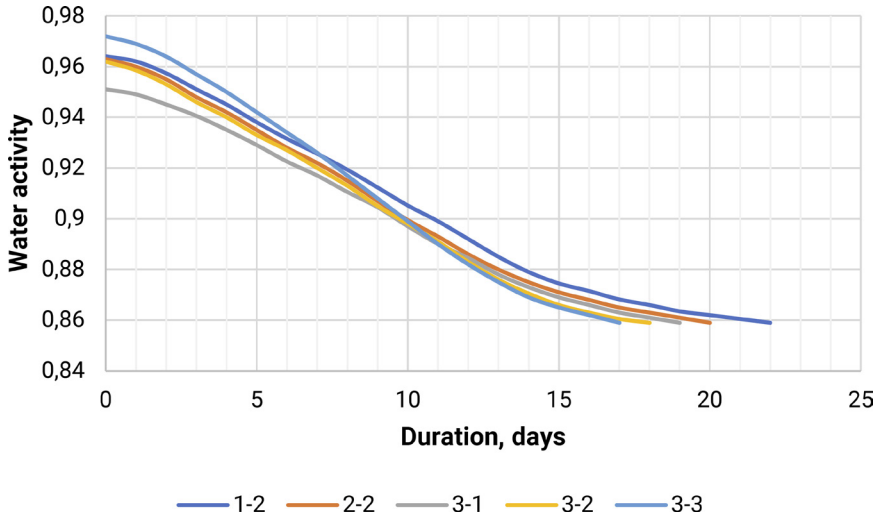

Figure 2. Water activity changing model sausage samples

TABLE 5.
Model Sausages' Overall Composition and Chemical Properties

Sample	Weight percentage/fraction (%) of:				Value:	
	moisture	fat	protein	salt	a_w	pH
1-2	30.7±0.4	22.8±0.5	38.2±0.7	5.11±0.12	0.859±0.001	5.53±0.03
2-2	39.7±0.5	26.1±0.6	30.0±0.5	5.84±0.09	0.860±0.002	5.61±0.02
3-1	33.5±0.2	31.7±0.4	27.0±0.6	5.54±0.15	0.858±0.002	5.56±0.02
3-2	27.1±0.3	36.6±0.4	30.3±0.8	4.46±0.10	0.860±0.001	5.49±0.03
3-3	18.6±0.4	40.7±0.5	32.4±0.7	3.08±0.13	0.859±0.000	5.40±0.01

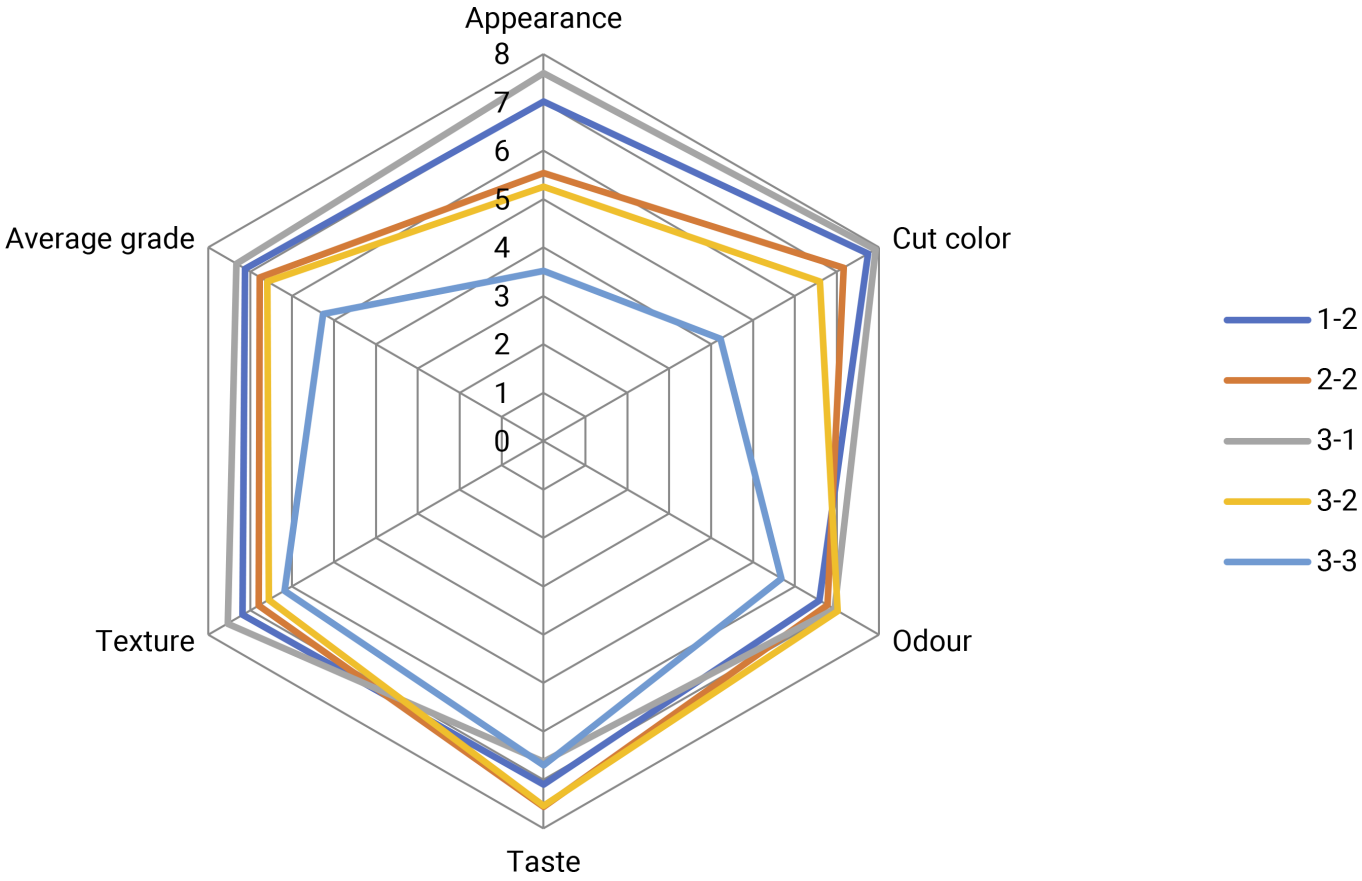

Figure 3. Sensory profiles of model sausage samples

raw smoked sausages it was found out that the 1.5% ground meat salt content yields the lowest average grade (5.26) among all the samples, the appearance and the cut color being graded below the acceptance level at 3.52 and 4.22 respectively. The most preferable organoleptic parameters were demonstrated by sample 3-1 featuring the ground meat salt content of 3.5% and beef-to-fat ratio of 80/20. The final product salt content is 5.54% which is lower than that required by the pertinent standards but not favorable from the food safety viewpoint. The samples with the 2.5% ground meat salt content were given intermediate grades ranging from 6.60 (3-2) to 7.12 (1-2).

Conclusions

The performed analysis and tests have yielded the following conclusions.

1. The ground meat with salt content not exceeding 1.5% of the weight of the unsalted primary products cannot be accepted for raw smoked sausage production as incapable of ensuring both the traditional organoleptic features and sufficient product yield.

2. The raw smoked sausage fat content can be decreased by increasing the ratio of lean meat to fatty tissue but only provided that the quantity of salt added to the ground meat is maintained at 2.5% or higher.

On a final note it should be emphasized that forecasting of the changes of the ground meat overall chemical composition and its physical and chemical properties (above all the weight percentage of moisture and water activity) when elaborating technologies to make new raw smoked sausage sorts and improve the existing ones facilitates obtaining of products with precalculated composition and properties including ensured safety level and reasonable economic feasibility.

In our opinion it would be beneficial to carry out further research focused at a narrower range of ground meat salt content, namely within 2.0% through 2.4%, which is demonstrated by the materials offered herein.

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