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Sensory and Chemical Quality Deviations of Popularly Manufactured Dry Sausage

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Abstract

Traditional dry sausages are one of the meat products that target globally by thousands of meat consumers. From a consumer perception point of view, the quality of this traditional meat product is of great concern. Therefore, this study was conducted to evaluate the sensory and chemical quality of 100 samples of dry sausage marketed in Ismailia city, Egypt. Only 22 dry sausage samples were accepted in concern to their appearance and 56 samples were accepted in concern to their flavor. Out of 78 samples rejected for appearance, 43 (overfilling), 12 (fading) and 23 (discolored) rejected sausage samples. Out of 44 samples rejected for flavor, 28 (rancid), 10 (sour), and 6 (putrid) rejected sausage samples. The mean values of moisture, protein, fat, ash, CHO, and NaCl contents for dry sausage samples were 43.7, 15.3, 19.9, 4.3, 13.6, and 3.2 respectively. 90% of sausage samples corresponded with the standard limit of moisture content. Commercial fraud during the manufacture of the dry sausage was detected based on their protein content whereas 56% of the sausage samples were unfit with the requirement of Egyptian Standard for protein contents. The mean pH, TBA and TVB-N values for the examined dry sausage samples were 5.1, 0.9 (mg/Kg), and 14.9 (mg/100g) respectively. It could be concluded that a considerable number of dry sausage samples had deviation in their sensory and chemical quality and may have a negative effect on consumer satisfaction.

KEYWORDS
Chemical quality, Dry sausage, Meat products, Meat quality.

INTRODUCTION

Dry food is one a popular product since ancient Egyptians. Dry sausages are one of the traditional meat products targeted by thousands of meat consumers worldwide. Such dry sausage (fermented without a starter) is locally processed using lean meat, non-meat ingredients, and additives (salt, herbs, spices, etc.) that are stuffed into casings and then dried to obtain a specific flavor and appearance. Nowadays, the production of dry sausages is increasing in industrial conditions; consequently, it is necessary to define techniques that will ensure the product's quality and safety (Dzinic *et al*., 2015). Meat processing flourished on a wide scale, especially during the last three decades. Before that time, meat processing had been practiced by butchers in their shops to utilize the non-marketable meat cuts which do not find a market but are still suitable for human use, like meat enter into secondary products such as dry sausage.

Meat products are mainly traded at chilled temperatures, their qualities are a major concern for retailers, consumers, and public health. However, due to microbial development, various unwanted changes in the items might occur under refrigeration, leading to meat spoilage, and quality loss which results in an economic loss (Elabbasy *et al*., 2014). The sensory and chemical quality of dry sausage is one of great concern because it is related to consumer perception, thus it must be ensured at every level of the food chain to the end products for the consideration of conscious customers. The sensory analysis of dry sausage provides solid and important data related to the organoleptic profile associated with consumer preference. Sensory characters were more efficient than physicochemical factors in distinguishing between traditional and industrial sausages. Consumers defined and differentiated the samples using the check-all-that-apply technique, establishing a standard for accepted hedonic characters of fermented sausages (Bonacina *et al*., 2020). Available data on the proximate composition of dry sausage assist consumers to decide quality choices. A recent study done by Khairy *et al*. (2021) confirmed the proximate chemical analysis of dry sausage from different markets showed wide varieties of proximate compositions due to their different processing methods.

From a consumer perception point of view, the quality of meat products is of great interest. In addition, further development of the safety and quality of dry sausages is recommended (Sirini *et al*., 2022). Therefore, this survey was conducted to evaluate sensory and chemical quality parameters of traditional

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dry sausage randomly collected from different markets in Ismailia city, Egypt.

MATERIALS AND METHODS

Collection of samples

A total of 100 samples of dry sausage were randomly collected from different street vendors, butchery, major supermarket chains, independent supermarkets, and Souk located in Ismailia city, Egypt. Each sample was aseptically handled, identified, individually packed in a sterile polyethylene bag as a complete intact unit, and transferred in an icebox, to keep the sensory and chemical state, immediately with a minimum delay to Animal Health Research Institute laboratory, Damietta port laboratory for evaluation.

Sensory evaluation

A panel consisting of five trained members of the same ages performed the sensory evaluation of dry sausage samples. Evaluations were performed according to panels rejected or accepted based on the sample's appearance and flavor according to Holman *et al*. (2019).

Proximate chemical analysis

The chemical analysis of dry sausage samples was done according to the recommended technique by AOAC (2003) for moisture, fat, total protein, Ash, carbohydrate, and ISO standard No. 1841-1/1996 for sodium chloride content.

Deterioration of chemical quality

The chemical criteria of dry sausage samples for pH assessment (ISO 2917:1999 & ES/63-11, 2006), Pearson 1981 & ES: 63-9/2006 for determination of total volatile bases nitrogen (TVB-N) and Pearson's 1981 & ES: 63-10 /2006 for determination of thiobarbituric acid number (TBA).

Statistical analysis

All results were submitted to descriptive analysis by Excel 2019 and expressed as mean ± SE, minimum and maximum.

RESULTS AND DISCUSSION

Sensory examination

Generally, purchasing any meat products by consumers is motivated by their appearance and flavor (Bekhit *et al*., 2021). The results in Table 1, summarize the number of sausage samples based on acceptance or rejection by panelists. Out of 100 examined samples, only 22 dry sausage samples were accepted in concern to their appearance, and 56 dry sausage samples were accepted in concern to their flavor.

The normal appearance of traditional dry sausage is a marbling appearance, such appearance is mainly due to there being no emulsion developed during its manufacture, consequently, easily distinguish the marbling appearance of the product as fat particles are staggered with meat. The characteristics of flavor in traditional dry sausages are mainly derived from lipid oxidation and hydrolysis, changes in neutral lipids, free fatty acids, and phosphatides.

The results in Table 2, revealed the reasons for acceptance and rejection of dry sausage samples based on their appearance and acceptance. Out of 78 samples rejected for appearance, 43 (overfilling), 12 (fading) and 23 (discolored) rejected sausage samples. Out of 44 samples rejected for flavor, 28 (rancid), 10 (sour), and 6 (putrid) rejected sausage samples.

Overfilling is mainly due to traditional manual processing of some samples meanwhile fading of some samples may interpret for their higher salt contents and abused storage conditions. Abnormal color may be attributed to the use of legumes in sausage recipes especially soy proteins as meat binders and as a cheap source of protein. This explanation is matching with the findings of Syamsuri *et al*. (2020) who used different soybean varieties in tempeh sausage and illustrated the brown color of the sausage found by the panelists which resulted from protein amino acids reactions with carbonyl compounds. Other abnormal discoloration of dry sausage samples can be attributed to the growth of different species of enterococci and lactic acid bacteria (Grant *et al*., 1988; Borch *et al*., 1988; Jay *et al*., 2005).

The flavor is created through a complex process involving several enzymatic activities and chemical reactions (Toldra, 1998). The normal characteristics of flavor for dry sausage developed due to the presence of carbohydrates, starter cultures, meat proteins, and lipids hydrolysis during drying and fermentation generate aroma precursors such as free amino acids, and free fatty acids which are substrates of microbial and chemical reactions producing volatile aroma compounds (Sirini, *et al*., 2022). Other abnormal flavors (rancid, sour, and putrid) of dry sausage samples are likely to be due to the microbial spoilage and oxidative rancidity done under abusive storage conditions (Monahan *et al*., 1992). Souring and putrefaction are common defects in dry sausage due to the growth of halophilic microorganisms, especially during a long storage period (Aiedia-Hoda, 1995).

Proximate chemical analysis of dry sausage

The chemical properties of dry sausage can provide beneficial information regarding the nature of its composition. The

Table 1. Sensory evaluation of dry sausage (n=100).

	Appearance		Flavour	
	Panels Accepted	Panels Rejected	Panels Accepted	Panels Rejected
Samples Number	22	78	56	44

Table 2. Dry sausage samples rejections based on their appearance and flavour (n=100).

	Abnormal flavour			Abnormal appearance		
Samples Number	Over filling	Fading	Discolored	Rancid	Sour	Putrid
	43	12	23	28	10	6

results in Table 3, had shown the proximate chemical analysis of dry sausage samples. The mean values of moisture, protein, fat, ash, CHO, and NaCl contents for dry sausage samples were 43.7, 15.3, 19.9, 4.3, 13.6, and 3.2 respectively. Egyptian organization for standardization and quality control (ES: 4177/2005) sets the standard limit of moisture content in dry sausage up to 55%. Based on this limit, 90% of sausage samples were corresponds to the standard limit of moisture content. Toldrá (2007) confirmed that a decrease in the moisture content of the dry sausage led to an increase in its shelf-life. The obtained results for moisture contents of dry sausage agree with many former studies (Aiedia-Hoda, 1995; Moretti *et al*., 2004; Assaye and Ashenafi, 2014; De Mey *et al*., 2014). High moisture contents in dry sausage recorded by Jin *et al*. (2018) were attributable to the lower pH of the examined dry sausage samples.

In concern of protein contents of dry sausage with the Egyptian standard, 56% of the examined sausage samples were in compliance with the standard limit (up to 15%) and the other 44% of the samples were less than the requirements of the standardization. These results declared commercial fraud during the manufacture of dry sausage; this could be demonstrated by the too much incorporation of filling materials, non-proteinous materials, in the formulation of the product such as the wheat flakes, and beetroot, as coloring materials, which reflected on the final protein content of sausage. Higher levels of protein content were recorded by De Mey *et al*. (2014) and Daszkiewicz *et al*. (2015). Fat plays a great role in meat manufacturing due to its effect on microbiological and sensory quality. Regarding the fat content, all dry sausage samples were accepted when compared with the Egyptian standard which stated the limit of fat up to 25%. A completely similar result was obtained by Aiedia-Hoda, (1995). Furthermore, the higher fat percentage in naturally processed salami was recorded by Moretti *et al*., (2004). However, lower fat percentage was observed by De Mey *et al*. (2014) and Daszkiewicz *et al*. (2015).

In this study, 12 of the samples exceeded the allowed limit of ash content as stated by the Egyptian standard. Lower results of ash content in dry sausage were noted by Daszkiewicz *et al*. (2015) who found that the ash content in dry sausage samples was 3.98±0.39, which was due to the poor quality of raw meat used.

Sodium chloride is an important ingredient in dry sausages. NaCl plays a great role in myofibrillar protein solubilization, enhancing water binding and water retention capacity, decreasing water activity, improving sensory characteristics, and finally, controlling enzymatic and biochemical reactions during ripening (Pires *et al*., 2017). In this study, 48% of the examined sausage samples were found above the standard limits (3.25%). Slightly higher results for NaCl contents of dry sausage were recorded by De Mey *et al*. (2014). However, the global daily sodium intake is estimated at 9–12 g (Pateiro *et al*., 2021).

Moisture/protein ratios (MPR) are commonly used to differentiate dried sausages and other meat products. Food Safety and Inspection Service established standards specified for MPR as 1.9:1 or less to ensure a safe product with a good shelf-life. From the results of the current study, 72% of the dry sausage samples were below the acceptable ratio stated by ISO-23854 (2021), while 28% of sausage samples were above this ratio. Although all moisture contents of the investigated sausage samples were in compliance with the Egyptian standard, this variation may be occurred by the faulty formulation of sausage by incorporating too many carbohydrates and non-meat components which result in a reduction of protein content in the final product and aimed to decrease the cost of production and achieve more profits. Consequently, the final product will have organoleptic defects.

Chemical quality parameters

For consumers, meat product is considered spoiled if undesirable changes are detected in their sensory characteristics which mainly interpret the chemical changes in the final meat product during and after manufacture (Fletcher *et al*., 2018). The results in Table 4, clarified the chemical quality parameters of dry sausage samples. The mean pH, TBA and TVB-N values for the examined dry sausage samples were 5.1, 0.9 (mg/Kg), and 14.9 (mg/100g) respectively.

The pH value of dry sausage is the most important chemical characteristic affecting its quality and shelf-life. Egyptian Slandered doesn't set a permissible limit for pH in dry sausage, On the other hand, he accepted limit of pH in dry sausages should reach the ultimate 4.7 to 5.0 (USDA-FSIS, 2005). Therefore, 16% of the marketed dry sausage samples were unfit for human consumption due to low pH content; meanwhile, 84% of the examined sausage samples were fit. The decline in pH values in dry

Table 3. Statistical analysis of proximate chemical analysis of dry sausage (n.=100).

	~Min. (%)	`Max. (%)	Mean±S.E.	*Exceed E.S.	Within E.S.
Moisture	37.40	51.30	43.7±0.41	10.00%	90.00%
Protein	11.40	19.20	15.3±0.21	56.00%	44.00%
Fat	15.10	24.3	19.9±0.26	0.00	100.00%
Ash	2.45	5.50	4.3±0.08	12.00%	88.00%
@CHO	8.04	19.53	13.6±0.33	20.00%	80.00%
Sodium Chloride	2.30	4.70	3.3±0.05	52.00%	48.00%
**M/P ratio	2.02	4.50	2.9±0.06	28.00%	72.00%

~Min.: Minimum; Mix.: Maximum; *E.S.: Egyptian Standard; @CHO: Carbohydrate; ** M/P ratio: Moisture/protein ratio

Table 4. Statistical analysis of chemical quality parameters of dry sausage (n=100).

	Min.	Max.	Mean ± S.E.	ES >	ES <
pH	4.2	5.9	5.1 ± 0.05	*84%	*16%
TBA mg/kg	0.6	2.3	0.9 ± 0.04	72%	28%
TVB-N mg/100g	9.1	27.3	14.9 ± 0.44	88%	12%

*Based on USDA-FSIS, (2005)

sausage below the standard limit (4.7) might be due to the bacterial multiplication-induced accumulation of organic acids (Wang *et al*., 2022). The presence of high counts of lactic acid bacteria enhanced the proteolytic activities counteracting the acid produced by lactic acid bacteria (Assaye and Ashenafi, 2014).

Lipid oxidation in meat products is contributed to the non-enzymatic lipid oxidation more than other lipid oxidation pathways (Papuc *et al*., 2017). Thiobarbituric acid (TBA) value is used as a lipid oxidation index for many fatty foods. The acceptable limit set by ES (4177/2005) is a maximum of 0.9 mg/kg., thus, 28% of the examined sausage samples exceeded that permissible limit. Lipid oxidation (rancidity) is the reaction of unsaturated fatty acids with molecular oxygen causing fat deterioration. Three pathways of rancidity include photo-oxidation, autoxidation, and enzymatic hydrolysis, with little significance for the last pathway in meat products (Mariutti and Bragagnolo, 2017). Lipid oxidation is mediated by the actions of lipoxygenases, lipases, and cyclooxygenase enzymes which are secreted by spoilage microorganisms. Although the activity of these lipases decreases during the drying process, these enzymes remain active during the entire process for dry sausages (Ragab, 2011).

Total volatile nitrogen (TVB-N) content is used as an indicator for tissue protein breakdown caused by proteolytic enzymes due to microbial activities during the storage of meat products (Ruan *et al*., 2019; Wang *et al*., 2020). The acceptable limit for TVB-N in meat products is set by ES (4177/2005) as a maximum of 20 mg/100g. thus, 12% of the examined samples exceeded the TVB-N limit and 88% were within that limit. TVB-N accumulation increases over time of storage and goes parallel to other spoilage biomarkers (Huang, *et al*., 2014). An increase the enzymatic activities, particularly, the protease enzyme produced by certain microorganisms leads to an increase in TVB-N production because of the degradation of protein structures of the sausage (Huang *et al*., 2014). Similar results were obtained by Ragab (2011).

CONCLUSION

It could be concluded that a considerable number of dry sausage samples had deviation in their sensory and chemical qualities and may have a negative effect on consumer satisfaction. Ingredients used in dry sausage production with abused storage conditions can influence the final product quality. Therefore, the traditional dry sausage quality mustn't be lost by using good quality raw ingredients and application of good hygienic practices during manufacturing.

CONFLICT OF INTEREST

Authors declare that they have no conflict of interest.

REFERENCES

Aiedia-Hoda, A.M., 1995. Quality investigation into room kept traditional meat products in Egypt. Ph.D. Thesis, Fac. Vet. Med. Cairo Univ., Egypt.

AOAC, 2003. Official Methods of Analysis. Vol. I, 17th ed. Association of Analytical Washington, DC, USA.

Assaye, H., Ashenafi, M., 2014. Microbiological profile of retail sliced dry sausages in Ethiopia. International Food Research Journal 21, 6.

Bekhit, A.E.D.A., Holman, B.W., Giteru, S.G., Hopkins, D.L., 2021. Total volatile basic nitrogen (TVB-N) and its role in meat spoilage: A review. Trends in Food Science and Technology 109, 280-302.

Bonacina, M., Silva, G.S.D., Mitterer-Daltoé, M.L., 2020. Physicochemical quality and consumer discrimination of industrial and traditional fermented sausages. Ciência Rural 50,7.

Borch, E., Nerbrink, E., Svensson, P., 1988. Identification of major contamination sources during processing of emulsion sausage. International Journal of Food Microbiology 7, 317-330.

Daszkiewicz, T., Markowski, M., Zapotoczny, P., Winarski, R., Kubiak, D., Hnatyk, N., Koba-Kowalczyk, M., 2015. Chemical composition and pH of processed pork meat products supplied by a renowned polish manufacturer. Polish Journal of Natural Sciences 30, 275-283.

De Mey, E., De Klerck, K., De Maere, H., Dewulf, L., Derdelinckx, G., Peeters, M.C., Fraeye, I., Vander Heyden, Y., Paelinck, H., 2014. The occurrence of N-nitrosamines, residual nitrite and biogenic amines in commercial dry fermented sausages and evaluation of their occasional relation. Meat Science 96, 821-828.

Dzinic, N., Ivic, M., Branislav, S., Jokanovic, M., Tomovic, V., Okanovic, D., Raljic, J.P., 2015. Some quality parameters of dry fermented sausages (*Čajna kobasica*). Procedia Food Science 5, 77-80.

Egyptian Organization for Standardization and Quality, 2005. Egyptian Standards Meat and meat products-Salami. E.S.: 4177-2005, ICS: 67.120.10

Elabbasy, M., Eldesoky, K., Morshdy A., 2014. Improvement the shelf life of minced beef. Life Science Journal 11, 185-190.

ES (Egyptian Organization for Standardization), 2006. Methods of analysis and testing for meat. Part 9: determination of total volatile nitrogen (TVN). ES:63–9/2006.

ES (Egyptian Organization for Standardization), 2006. Methods of analysis and testing for meat. Part 10: determination of thiobarbituric acid (TBA). ES: 63–10/2006.

Fletcher, B., Mullane, K., Platts, P., Todd, E., Power, A., Roberts, J., Chapman, J., Cozzolino, D., Chandra, S., 2018. Advances in meat spoilage detection: A short focus on rapid methods and technologies. CyTA-Journal of Food 16, 1037-1044.

Grant, G.F., McCurdy, A.R. and Osborne, A.D., 1988. Bacterial greening in cured meats: a review. Canadian Institute of Food Science and Technology Journal 21, 50-56.

Holman, B.W., Fowler, S.M. and Hopkins, D.L., 2019. Red meat (beef and sheep) products for an ageing population: a review. International Journal of Food Science & Technology 55, 919-934.

Huang, L., Zhao, J., Chen, Q., Zhang, Y., 2014. Nondestructive measurement of total volatile basic nitrogen (TVB-N) in pork meat by integrating near infrared spectroscopy, computer vision and electronic nose techniques. Food chemistry 145, 228-236.

ISO standard No. 1841-1/1996. Meat and meat products-Determination of chloride content –part 1: Volhard method. https://www.iso.org/obp/ui/#!iso:std:6498:en

ISO 2917:1999. International Organization for Standardization. Meat and meat products: measurement of pH (reference method) (ISO/DIS standard No. 2917). Geneva, Switzerland: ISO.

ISO-23854:2021. International Standard for Fermented meat products-Specification. First edition.

Jay, J., Loessner, M., Golden, D., 2005. Modern Food Microbiology. 7th ed. New York: Springer.

Jin, S.K., Hwang, J.W., Hur, S.J., Kim, G.D., 2018. Quality changes in fat-reduced sausages by partial replacing sodium chloride with other chloride salts during five weeks of refrigeration. LWT 97, 818-824.

Khairy N., Karmi M., Maky M., 2021. Proximate Composition Analysis of Beef Sausage. Aswan University Journal of Environmental Studies 2, 155–161.

Ragab, M.I., 2011. Determination of chemical parameters of beef and its products. Assiut Veterinary Medical Journal 57, 1-14.

Mariutti, L.R., Bragagnolo, N., 2017. Influence of salt on lipid oxidation in meat and seafood products: A review. Food Research International 94, 90-100.

Monahan, F.J., Gray, J.I., Booren, A.M., Miller, E.R., Buckley, D.J., Morrissey, P.A., Gomaa, E.A., 1992. Influence of dietary treatment on lipid and cholesterol oxidation in pork. Journal of Agricultural and Food Chemistry, 40, 1310-1315.

Moretti, V.M., Madonia, G., Diaferia, C., Mentasti, T., Paleari, M.A., Panseri, S., Pirone, G., Gandini, G., 2004. Chemical and microbiological parameters and sensory attributes of a typical Sicilian salami ripened in different conditions. Meat Science 66, 845-854.

Papuc, C., Goran, G.V., Predescu, C.N., Nicorescu, V., 2017. Mechanisms of oxidative processes in meat and toxicity induced by postprandial degradation products: A review. Comprehensive Reviews in Food Science and Food Safety 16, 96-123.

Pateiro, M., Munekata, P.E., Cittadini, A., Domínguez, R., Lorenzo, J.M., 2021. Metallic-based salt substitutes to reduce sodium content in meat products. Current Opinion in Food Science 38, 21-31.

Pearson, D., 1981. The Chemical Analysis of Foods. Churchill Livingstone, Edinburgh, UK, pp. 504-530.

Pires, M.A., Munekata, P.E.S., Baldin, J.C., Rocha, Y.J.P., Carvalho, L.T., dos Santos, I.R., Barros, J.C., Trindade, M.A., 2017. The effect of sodium reduction on the microstructure, texture and sensory acceptance of Bologna sausage. Food Structure 14, 1-7.

Ruan, C., Zhang, Y., Sun, Y., Gao, X., Xiong, G., Liang, J., 2019. Effect of sodium alginate and carboxymethyl cellulose edible coating with epigallocatechin gallate on quality and shelf life of fresh pork. International Journal of Biological Macromolecules 141, 178-184.

Sirini, N., Munekata, P.E., Lorenzo, J.M., Stegmayer, M.Á., Pateiro, M., Pérez-Álvarez, J.Á., Sepúlveda, N., Sosa-Morales, M.E., Teixeira, A., Fernández-López, J., Frizzo, L., 2022. Development of Healthier and Functional Dry Fermented Sausages: Present and Future. Foods 11, 1128.

Syamsuri, R., Dewayani1, W., Septianti, E., Maintang, S., 2020. Chemical characteristic and sensory of tempeh sausage on different soybean varieties and cooking methods variation. IOP Conf. Series: Earth and Environmental Science, p. 575.

Toldrá, F., 2007. Handbook of Fermented Meat and Poultry. Iowa, USA: Blackwell Publishing.

Toldra, F., 1998. Proteolysis and lipolysis in flavour development of dry-cured meat products. Meat Science, 49, S101-S110.

USDA–FSIS, 2005. Meat and poultry hazards and controls guide. Available from: http://www.fsis.usda.gov/oppde/rdad/fsisdirectives/5100.2/meatand poultry hazards controls guide 10042005.

Wang, J., Hou, J., Zhang, X., Hu, J., Yu, Z., Zhu, Y., 2022. Improving the Flavor of Fermented Sausage by Increasing Its Bacterial Quality via Inoculation with Lactobacillus plantarum MSZ2 and Staphylococcus xylosus YCC3. Foods 11, 736.

Wang, Z., He, Z., Zhang, D., Li, H., Wang, Z., 2020. Using oxidation kinetic models to predict the quality indices of rabbit meat under different storage temperatures. Meat Science 162, 108042.