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THE USE OF MUTTON IN SAUSAGE PRODUCTION

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ABSTRACT

The work analyzes the quality of sausage with mutton. The proportion of individual commodities was as follows 40% sheep thigh, 40% pork shoulder, and belly 20%. The protein content in pork shoulder was 20.11 g.100g^{-1} in sheep thigh 23.65 g.100g^{-1} and sausage 19.89 g.100g^{-1}. Of the monitored amino acids, the highest content was in lysine, in the sausage was 1.9 g.100g^{-1} and of the raw materials in the belly 2.1 g.100g^{-1}. We also found a higher proportion of leucine 1.7 g.100g^{-1} in both sausage and sheep thighs. The arginine content in the sausage was also high 1.39 g.100g^{-1}. We found a high content of palmitic acid in the pork shoulder of 24.38 g.100g^{-1} FAME. The content of palmitic acid in sheep meat was 24.32 g.100g^{-1} FAME and in sausage 24.16 g.100g^{-1} FAME. The content of stearic acid in the pork shoulder was 10.89g.100g^{-1} FAME, in the sheep thigh 10.64g.100g^{-1} FAME, in the belly 11.07 g.100g^{-1} FAME, and the sausage 10.92 g.100g^{-1} FAME. The MDA content in sheep meat was 0.185 mg.kg^{-1}, in pork shoulder 0.141 mg.kg^{-1}, in pork belly 0.22 mg.kg^{-1} and in sausage on the day of production 0.45 mg.kg^{-1}. On the 30th day, the MDA content was in the sausage 0.78 mg.kg^{-1}. The high MDA content of the sausage was probably most influenced by the technological process, as all raw materials, because there was a lower MDA content.

Keywords: meat; sausage; fatty acids; malondialdehyde

INTRODUCTION

According to Commission Delegated Regulation **(EU) 2017/1182**, sheep carcasses to 1 year old are classified as lambs and adult sheep over 1 year old. The meat of adult sheep has very good sensory and technological properties, but the consumer perceives it to a certain extent negatively. If the meat is used in meat products, the producer must declare his content in the final product.

In Slovakia, pork is the most preferred type of meat, whose chemical composition may vary depending on the topographic origin. In pork, depending on the cut parts, the protein content is 9% – 20% **(Poráčová et al., 2017)**. Meat quality is defined as a combination of basic meat characteristics **(Čuboň et al., 2017)**.

It is the first sign that the consumer notices and thanks to which he also makes a decision. The color of the meat is determined by the state of myoglobin, oxymyoglobin is bright red and metmyoglobin is brown **(Ning et al., 2019)**.

The color of the cut ripened pork is pale pink and its taste depends mainly on various factors such as the age of the animal and its method of feeding. The meat of younger animals is paler and suitable for cutting. Older individuals have dark red meat and are suitable for the production of mainly durable meat products **(Holland et al., 1991)**.

Pork has an optimal content of unsaturated fatty acids and also shows a good representation of essential substances and minerals. From a nutritional point of view, it is an important source of animal protein **(Fuastman and Suman, 2017)**.

In lean lamb meat contains about 20 – 25% of proteins, while in heat-treated meat their content is 28 – 36% because the water content in the meat is reduced and nutrients are concentrated during culinary processing. Protein digestibility is high, approximately 94% compared to beans (78%) or wheat (86%). Lamb meat contains all the essential amino acids **(Krishtafovich et al., 2016)**. According to **Williams (2007)**, the amino acids glutamine and glutamic acid are found in sheep meat in the largest amounts than in other types of meat. Other higher amino acids include arginine, alanine, and aspartic acid. The tryptophan content is highly variable depending on age and muscle area **Crăciun et al. (2012)**.

Sheepmeat contains saturated, monounsaturated, and polyunsaturated fatty acids, the content of which is optimal from a technological point of view and the point of view of a healthy diet **(Krishtafovich et al., 2016)**.

Sheep grazed on native pastures have a polyunsaturated fatty acid content of 200 – 500 mg.100g^{-1} of fresh meat, such meat is considered an appropriate source of polyunsaturated fatty acids **(Cabrera and Saadoun, 2014)**.

Fat oxidation during meat processing and storage is influenced by lipid content and composition **(Tsikas, 2017)**. Fat oxidation increases with the amount of fat and mainly depending on the ratio between PUFA and SFA **(Bertolín**

and Blanco, 2019). Lipid oxidation is a complex chain reaction process that results in the presence of reactive oxygen species, such as the superoxide radical anion. The peroxide non-radical anion can be produced by enzymes and non-enzymatic chemical reduction of molecular oxygen **(Cunha et al., 2018)**. Reactive oxygen species react with various biomolecules, e.g. PUFAs, forming aldehydes, ketones, acids, alcohols, and hydrocarbons that cause undesirable changes in structure, taste, and also color. Finally, they reduce the quality of the product until it becomes unfit for human consumption **(Jung et al., 2016)**.

Sensory and nutritional value are greatly affected by lipid oxidation, which is an undesirable manufacturing process. Oxidation causes the formation of aldehydes and ketones, which result in an unpleasant taste and smell of meat **(Bobko et al., 2015)**.

Lipid oxidation results in the formation of aldehydes. The most common aldehyde produced by damaging the polyunsaturated fatty acids is malondialdehyde (MDA). It is a simple alkandial derived from malonic acid **(Čuboň et al., 2019)**.

Currently, one of the markers used to determine the degree of lipid oxidation in meat and meat products is malondialdehyde, which is formed as a secondary product of lipid oxidation. The MDA content of meat is determined using thiobarbituric acid reactants (TBARS) **(Tsikas, 2017)**.

Meat and meat products are susceptible to quality deterioration due to their rich nutritional composition **(Bobko et al., 2017)**.

Jung et al. (2016) and **Bertolín and Blanco (2019)** report that TBARS is used to determine the degree of lipid oxidation in meat and meat products.

The excessive content of biogenic amines causes undesirable sensory properties. From a hygienic point of view, biogenic amines serve as indicators degree of food spoilage **(Čuboň et al., 2015)**.

Scientific Hypothesis

The aim of the work was the analysis of the basic chemical composition, fatty acids, amino acid content, and fat oxidation in sausage with the proportion of mutton and the raw material.

MATERIAL AND METHODOLOGY

Samples

Pork shoulder, pork belly, sheep thigh, sausage.

The individual commodities were used in the product as follows: 40% lamb thigh, 40% pork shoulder, and belly 20%. The meat was cut into smaller pieces and then minced on a grinder with 3 mm holes. Subsequently, the ingredients were added and the work was mixed thoroughly. The meat work lasted several tens of minutes to 1 hour and then stuffed into pork intestines. The sausages were smoked in a traditional smokehouse with cold smoke.

Ingredients per 10 kg of sausage: salt 20 dkg, ground red pepper 100 g, 5 head garlic, ground cumin 25 g, cumin whole 25 g, ground black pepper 28 g.

Laboratory Methods

Sausage samples were analyzed by FT-IR analysis (Nicolet 6700) of chemical composition, 100 g of sausages were taken. Subsequently, the samples were homogenized and analyzed. The method is based on the absorption of infrared radiation during the passage through the sample, during which changes in the rotational vibrational energy states of the molecule take place depending on changes in the dipole moment of the molecule. The resulting infrared spectrum is the functional dependence of energy, mostly expressed as a percentage of transmittance or units of absorbance at the wavelength of the incident radiation. The results of this analysis are given in $g.100g^{-1}$. Selected analyzed parameters of chemical composition were: content of proteins, water, lipids, omega 3 and 6 fatty acids, cholesterol, essential and selected non-essential amino acids, the content of selected monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), saturated fatty acids (SFA) and their total content in sausages.

Oxidative stability analysis by determining the concentration of malondialdehyde as the final oxidation product of the fat component of rabbit meat by the TBA (thiobarbiturate) method was performed on days 1 and 30 of sausage storage. The principle of the method is the spectrophotometric determination of the color complex, which is formed by the reaction of 2 molecules of TBA and the content of malondialdehyde (MDA) at a wavelength of 532 nm.

Approach:

- Weigh 1.5 g of the ground sample into a 50 mL centrifuge tube,
- addition of 1 mL EDTA (complexing agent) + mixing,
- add 5 mL of 0.8% BHT + mix,
- before homogenization, add 8 mL of 5% TCA,
- homogenization of 30 solutions 10,000 rpm,
- sample standing for 10 minutes followed by centrifugation for 5 minutes (3,500 x g, 4 °C),
- removal of the hexane layer after centrifugation and subsequent filtration of the samples,
- make up to 10 mL with 5% TCA,
- add 1 mL TBA to 4 mL sample,
- incubation in a water bath for 90 min at 70 °C,
- cooling and tempering to room temperature 45 min,
- extinction of samples for UV-VIS spectrophotometry at a wavelength of 532 nm,
- recalculation of the obtained data and determination of the concentration of malondialdehyde in $mg.kg^{-1}$ **(Marcinčák et al., 2005)**.

Statistical Analysis

The measured results of the analyzes were varied and statistically processed by SAS (2008) 9.3 Enhanced Logging Facilities, Cary, NC: SAS Institute Inc., 2008. We also processed the data of the analyzed parameters in Microsoft Excel.

RESULTS AND DISCUSSION

Table 1 shows the results of the basic chemical component of pork shoulder, sheep's thigh, pork belly, and sausage. The water content in the pork shoulder was 69.31 $g.100g^{-1}$, in the sheep's thigh 73.34 $g.100g^{-1}$, in the belly only 60.91 $g.100g^{-1}$ and in the sausage, the content was lower (62.34 $100g^{-1}$). The protein content in the pig's shoulder was 20.11 $g.100g^{-1}$, 23.65 $g.100g^{-1}$ in the sheep's thigh, and only 12.6 $g.100g^{-1}$ in the belly. We found in sausage a protein content of 19.89 $g.100g^{-1}$. However, the fat content was lowest in the sheep's thigh (2.11 $g.100g^{-1}$), higher in the sausage 14.04 $g.100g^{-1,}$ and highest in the pig belly 24.6 $g.100g^{-1}$. Consistent with our results **Nowak et al. (2016)** report a water content of 62.46 $g.100g^{-1}$, a fat content of 20.02 $g.100g^{-1}$, and lower protein content of 17.52 $g.100g^{-1}$. **(Rudy, 2009)** states in the mutton, under our results, in the first water content 72.80 $g.100g^{-1}$, fat content 3.60 $g.100g^{-1,}$ and protein 21.50 $g.100g^{-1}$. **Bertolín et al. (2018)** in contrast to our results report a higher cholesterol content of 0.69 $g.100g^{-1}$ in sheep meat.

Of all the monitored amino acids (Table 2), the highest proportion was the amino acid lysine, in sausage 1.9 $g.100g^{-1}$, of the raw materials the highest content in the belly was 2.1 $g.100g^{-1}$. We also found a higher proportion in the leucine content of 1.7 $g.100g^{-1}$ in both sausage and lamb thighs. The arginine content in the sausage was also high at 1.39 $g.100g^{-1}$.

Cheng et al. (2017) report a lower lysine content in pork *Longissimus thoracis* 0.98 $g.100g^{-1}$ compared to our results. **Marti-Quijal et al. (2019)** in turn report a lower lysine content of 1.36 $g.100g^{-1}$ in the sausage. Lower lysine content in mutton (0.79 $g.100g^{-1}$) is reported by **Huang et al. (2020)**.

Cheng et al. (2017) and **Huang et al. (2020)** compared to our results report a lower methionine content in pork 0.28 $g.100g^{-1}$ and mutton 0.33 $g.100g^{-1}$.

Cheng et al. (2017) found a lower threonine content of 0.70 $g.100g^{-1}$ in pork *Longissimus thoracis*. Also, **Huang et al. (2020)** also found a lower threonine content of 0.550 $g.100g^{-1}$, but **Marti-Quijal et al. (2019)** found a lower threonine content of (0.69 $g.100g^{-1}$) in pork sausage compared to our results.

Jia et al. (2019) found out a higher content of isoleucine in pork (0.91 $g.100g^{-1}$) compared to our results. On the other hand, **Huang et al. (2020)** report a lower isoleucine content (0.44 $g.100g^{-1}$). **Marti-Quijal et al. (2019)** report a lower isoleucine content of 0.73 $g.100g^{-1}$ in the sausage compared to our results.

Higher content of phenylalanine in pork than 1.37 $g.100g^{-1}$ was found by **Jia et al. (2019)**. **Marti-Quijal et al. (2019)** found in the sausage its lower phenylalanine content 0.662 $g.100g^{-1}$ compared to our results. Also, **Huang et al. (2020)** found a lower phenylalanine meat mutant content of 0.49 $g.100g^{-1}$ compared to our results.

A lower histidine content of 0.6 $g.100g^{-1}$ in pork was found by **Jia et al. (2019)**. Similarly, **Huang et al. (2020)** found a lower content of histidine (0.62$g.100g^{-1}$) compared to our results, but in mutton meat. **Marti-Quijal et al. (2019)** found a lower content of histidine in the sausage (0.852 $g.100g^{-1}$) compared to our results.

Table 3 shows the content of fatty acids in the raw material and sausage, the highest proportion of all fatty acids is oleic acid, of which 36.63 $g.100g^{-1}$ FAME in pork shoulder. **Aali et al. (2017)** report a higher oleic acid content in sheep *longissimus dorsi* (38.30 $g.100g^{-1}$ FAME) compared to our results. The content of oleic acid in the belly was up to 60.33 $g.100g^{-1}$ FAME and in the sausage 55.52 $g.100g^{-1}$ FAME. Compared to our results, **Cruxen et al. (2018)** found out lower oleic acid content in mutton sausage (41.25$g.100g^{-1}$ FAME).

We also found high content in the proportion of palmitic acid, in pork shoulder 24.38 $g.100g^{-1}$ FAME. Consistent with our results **Kim et al. (2009)** found out palmitic acid content in pork 24.17$g.100g^{-1}$ FAME. We found a palmitic acid content of 24.32 $g.100g^{-1}$ FAME in the sheep's thigh. Compared to our results **Chikwanha et al. (2018)** found out lower content of palmitic acid in sheep meat (22.2 $g.100g^{-1}$ FAME). The palmitic acid content of the sausage was 24.16 $g.100g^{-1}$ FAME, the lower content (23.03 $g.100g^{-1}$ FAME) is reported by **Cruxen et al. (2018)**.

Table 1 Chemical composition of raw material and sausage ($g.100g^{-1}$ ±*SD*).

Parameter	Pork shoulder	Sheep thigh	Pork belly	Sausage
Water	69.31 ±1.21	73.34 ±1.03	60.91 ±1.53	62.34 ±2.14
Protein	20.11 ±0.47	23.65 ±1.14	12.60 ±0.54	19.89 ±2.19
Fat	8.93 ±1.01	2.11 ±0.4	24.60 ±1.85	14.04 ±4.67
Cholesterol	0.61 ±0.16	0.51 ±0.08	2.12 ±0.17	1.65 ±0.54

Table 2 Amino acid content of raw material and sausage ($g.100g^{-1}$ ±*SD*).

Parameter	Pork shoulder	Sheep thigh	Pork belly	Sausage
Protein	20.11 ±0.47	23.65 ±0.14	12.60 ±0.54	19.89 ±2.19
Lyzin	1.71 ± 0.57	1.73 ±0.28	2.1 ±0.37	1.90 ±0.05
Leucin	1.57 ±0.09	1.7 ±0.25	1.71 ±0.33	1.7 ±0.05
Metionin	0.66 ±0.23	0.67 ±0.07	0.99 ±0.12	0.82 ±0.01
Treonin	0.81 ±0.24	0.79 ±0.12	0.61 ±0.14	0.89 ±0.04
Valin	0.82 ±0.19	0.82 ±0.09	0.82 ±0.11	0.79 ±0.05
Izoleucin	0.78 ±0.27	0.79 ±0.14	0.74 ±0.17	0.85 ±0.03
Histidin	0.86 ±0.31	0.82 ±0.11	0.81 ±0.14	0.85 ±0.06
Fenylalanin	0.81 ±0.25	0.82 ±0.12	0.77 ±0.6	0.88 ±0.03
Cystein	0.27 ±0.08	0.25 ±0.02	0.29 ±0.01	0.41 ±0.02
Arginin	1.273 ±0.42	1.29 ±0.12	1.20 ±0.18	1.39 ±0.04

Table 3 Content of fat (g.100g^{-1} ±*SD*) and fatty acids (g.100g^{-1} ±*SD* FAME) in the raw material and sausage.

Parameter	Pork shoulder	Sheep thigh	Pork belly	Sausage
Fat	8.93 ±1.01	2.11 ±0.4	24.60 ± 1.85	14.04 ±4.67
3 omega FA	0.53 ±0.01	0.54 ±0.26	0.85 ±0.11	0.7 ±0.04
6 omega FA	9.5 ±1.02	11.4 ±0.81	5.27 ±1.9	1.17 ±0.41
Esential FA	8.43 ±0.9	9.13 ±1.12	6.38 ±1.91	1.08 ±0.75
MUFA	49.62 ±2.02	47.78 ±0.79	69.93 ±1.94	60.92 ±1.61
PUFA	12.1 ±1.07	14.98 ±1.03	3.02 ±1.36	8.51 ±0.98
SAFA	34.21 ±2.21	33.52 ±1.31	26.49 ±1.05	28.24 ±2.06
C12:0 Lauric A.	0.12 ±0.03	0.11 ±0.003	0.02 ±0.01	0.06 ±0.01
C14:0 Myristic A.	1.35 ±0.02	1.38 ±0.04	1.23 ±0.02	1.31 ±0.09
C16:0 Palmit A.	24.38 ±1.4	24.32 ±0.31	24.01 ±0.1	24.16 ±0.18
C17:0 Heptadecanoid A.	0.31 ±0.03	0.30 ±0.03	0.12 ±0.02	0.19 ±0.04
C18:0 Stearic A.	10.89 ±0.03	10.64 ±0.31	11.07 ±0.09	10.92 ±0.17
9c-C18:1 Oleic A.	36.63 ±6.1	31.37 ±5.7	60.33 ±4.43	55.52 ±4.97
11c/15t-C18:1 Vakcen A.	4.78 ±0.1	4.91 ±0.18	4.35 ±0.06	4.58 ±0.05
C18:2 n-6 Linoleic A.	6.94 ±1.02	8.66 ±0.66	1.64 ±1.29	3.24 ±0.51
9c,11t 18:2 Conjugated Linoleic A.	0.13 ±0.02	0.13 ±0.01	0.06 ±0.01	0.09 ±0.02
C18:3 n-3 Linolenic A.	0.15 ±0.03	0.17 ±0.03	0.34 ±0.1	0.16 ±0.02
C20:1 Eikozenoic A.	0.51 ±0.17	0.54 ±0.11	1.26 ±0.15	0.99 ±0.12
C20:4 n6 Arachidonic A.	1.85 ±0.41	1.82 ±0.21	0.17 ±0.11	0.77 ±0.26
C20:5 n3 Eikozapentaenoic A.	0.097 ±0.02	0.1 ±0.02	0.01 ±0.00	0.04 ±0.01
C22:5 n-3 Dokozapentaenoic A.	0.13 ±0.01	0.14 ±0.02	0.11 ±0.00	0.12 ±0.01
C22:6 n-3 Dokozahexaenoic A.	0.03 ±0.03	0.04 ±0.01	0.04 ±0.00	0.04 ±0.003

Table 4 MDA content in raw material and sausage on the first and thirtieth day after production (mg.kg^{-1} ±*SD*).

Parameter	Pork shoulder	Sheep thing	Pork belly	Sausage	
				1-st day storage	30-th days storage
MDA	0.141 ±0.03	0.185 ±0.053	0.22 ±0.03	0.45 ±0.022	0.78 ±0.08

The content of stearic acid in the pork shoulder was 10.89 g.100g^{-1} FAME, in the sheep's thigh 10.64 g.100g^{-1} FAME, in the belly 11.07 g.100g^{-1} FAME, and in the sausage 10.92 g.100g^{-1} FAME. **Huang et al. (2020)** report a higher content of stearic acid in pork (11.07 g.100g^{-1} FAME) compared to our results. In contrast to our results, **Chikwanha et al. (2018)** found out higher content of stearic acid in mutton (18.1 g.100g^{-1} FAME) and **Marti-Quijal et al. (2019)** slightly higher values in sausage 13.51 g.100g^{-1} FAME.

Cheng et al. (2017) report an almost identical myristic acid content in pork of 1.44 g.100g^{-1} FAME compared to our values of 1.35 g.100g^{-1} FAME in pork shoulder and 1.31 g.100g^{-1} FAME in sausage. Higher content of myristic acid in the mutton 3.3 g.100g^{-1} FAME was found by **Chikwanha et al. (2018)** compared to our results 1.38 g.100g^{-1} FAME.

The content of eicosenic acid in the sausage was 0.99 g.100g^{-1} FAME, in the pork shoulder 0.51 g.100g^{-1} FAME, in the belly 1.24 g.100g^{-1} FAME and the sheep's thigh 0.54 g.100g^{-1} FAME. **Kim et al. (2009)** found a lower content of eicosenic acid (0.35 g.100g^{-1} FAME) in pork compared to our results and also **Chikwanha et al. (2018)** in mutton meat 0.45 g.100g^{-1} FAME. **Feng et al. (2020)** found a lower content of eicosenic acid in sausage (2.0 g.100g^{-1} FAME).

The content of docosahexaenoic acid in the pig's shoulder was 0.03 g.100g^{-1} FAME, in the sheep's thigh, in the belly and sausage was equally 0.04 g.100g^{-1} FAME. **Chikwanha et al. (2018)** reported up to 0.15 g.100g^{-1} FAME in comparison with our results in mutton meat, in contrast to **Cruxen et al. (2018)** in sausage 0.09 g.100g^{-1} FAME.

The highest MUFA content 69.93 g.100g^{-1} FAME in the belly was then in pork shoulder 49.62 g.100g^{-1} FAME, in mutton 47.78 g.100g^{-1} FAME, and sausage 60, 92 g.100g^{-1} FAME. SAFA content was 34.21 g.100g^{-1} FAME in pork shoulder, 33.52 g.100g^{-1} FAME in mutton, and only 28.24 g.100g^{-1} FAME in sausage. The PUFA content in the mutton was 14.98 g.100g^{-1} FAME, in the belly 3.02, and the sausage 8.51 g.100g^{-1} FAME. **Abdallah et al. (2020)** found out similarly with our results the MUFA content in mutton 46.9 g.100g^{-1} FAME, while **Cheng et al. (2017)** report only 41.60 g.100g^{-1} FAME in pork and **Marti-Quijal et al. (2019)** in sausage 48.84 g.100g^{-1} FAME. **Cheng et al. (2017)**, in contrast to our results, found a lower PUFA content of 15.14 g.100g^{-1} FAME, and compared to our study higher SAFA content in pork 39.99 g.100g^{-1} FAME identically also **Abdallah et al. (2020)** found out a higher SAFA content in mutton 36.7 g.100g^{-1} FAME.

The content of omega 3 FA was highest in the belly 0.85, lowest in the pork shoulder 0.53, and the sausage 0.7 g.100g^{-1} FAME. Consistent with our results, **Feng et al. (2020)** found in mutton sausage omega 3 FA content 0.75 g.100g^{-1} FAME.

Table 4 shows the content of malondialdehyde (MDA) as an indicator of oxidative stability in pork shoulder, belly, and mutton on the day of production. In sausage on the first and thirtieth day after production. The MDA content in mutton was 0.185 mg.kg^{-1}, in pork shoulder 0.141 mg.kg^{-1}, in pork belly 0.22 mg.kg^{-1} and in sausage on the day of production 0.45 mg.kg^{-1}. On day 30, the MDA content was in the sausage (0.78 mg.kg^{-1}). In comparison with our results **Marcinčák et al. (2005)** found out lower MDA content in pork 0.1166 mg.kg^{-1}, also **Reitznerová et al.**

(2017) found a lower content of MDA (0.055 mg.kg^{-1}). In sausage after ripening 1-month **Šojić et al. (2015)** found an MDA content of 0.520 mg.kg^{-1}. The high MDA content of the sausage was probably most influenced by the production process, as all raw materials had a lower MDA content.

CONCLUSION

The basic composition of sausage representation of individual ingredients. The lower water content was influenced by its content in the belly but also by the reduction during drying and smoking. The content of individual monitored amino acids corresponding to the raw material used. The SAFA content of the raw materials ranged from 26.49 to 34.21 g.100g^{-1} FAME and is generally considered sufficient for fat oxidation. Our results confirmed the increased content of MDA. The high MDA content of the sausage was probably most influenced by the production process, as all raw materials had a lower MDA content.

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