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THE PHYSICOCHEMICAL PROPERTIES OF OFFAL FROM PUŁAWSKA GILTS IN RELATION TO CARCASS MEATINESS*

Marek Babicz[1], Kinga Kropiwiec[1], Magdalena Szyndler-Nędza[2♦], Ewa Skrzypczak[3]

[1]Department of Pig Breeding and Production Technology, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland
[2]Department of Pig Breeding, National Research Institute of Animal Production, 32-083 Balice n. Kraków, Poland
[3]Department of Pig Breeding and Production, Poznań University of Life Sciences, Wołyńska 33, 60-637, Poznań, Poland
♦Corresponding author: magdalena.szyndler@izoo.krakow.pl

Abstract

The aim of this study was to determine the relationship between the meatiness of the Puławska pig carcass and selected physical and chemical parameters of pork offal. The study was conducted on a group of 50 porkers of the native Puławska breed, whose carcasses were classified into five classes: E, U, R, O, and P, covering 10 specimens each. Samples were collected from the tongue, heart, lungs, liver and kidneys, and the pH (pH_{45}, pH_{24}), percentage of free water and chemical composition (ash, fat, protein) were determined. To summarise the obtained results, it can be concluded that the increase of the meat content in carcass significantly and primarily affects the reduction of the offal's weight and then the reduction of the pH_{45} as well as the increase of the free water content primarily in the kidney and the lungs. In the case of chemical composition an increase of the meatiness in the carcass affected the reduction of fat content in the kidneys, lungs, heart and liver. The liver and the heart were the offal with the greatest susceptibility to the effects of the carcass meatiness. In this offal the increase of the carcass meatiness significantly decreased the fat content and energy value, and also increased the ash and protein content. Offal from the studied meatiness classes of the pigs' carcasses was characterised by adequate quality and suitability for processing.

Key words: EUROP carcass grading of pig, internal organs, native breed

Nowadays, the main purpose of pig production is to obtain the maximum value from porker slaughter, expressed in quantities of meat in the carcass and gaining

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valuable cuts. From an economic perspective, not only is the size important but also the quality of the primal cuts. One of the components of pork quality is the quality of technology, consisting of a collection of traits important in terms of utilisation and processing of meat (Florowski et al., 2013). The indicators used as the criterion for assessing the technological quality of meat are among others: water absorption, acidity, colour (Przybylski et al., 2012). In contrast, the nutritional value of the raw material is shaped by the content of ash, protein and fat (Czarniecka-Skubina et al., 2007). These components also allow attracting better consumer appeal towards the product (Sałyga et al., 2007). The rate of change or maintaining the pH value of the meat after a slaughter at a single level is a major determinant of its quality (Olszewski, 1999). The level of hydrogen ion concentration also affects the fragility and water absorbability of the raw material.

An analysis of the above parameters can also be used to evaluate the physicochemical quality of edible by-products (offal), which are mostly used in the production of offal cured meat (liver sausage, blood sausage, headcheese). The advantage of the manufacture of food products and dishes of offal, other than their high nutritional value, is mainly their lower price compared to the high-quality meat products (Toldra et al., 2012). It is clear from the literature data that offal (especially the liver) contains higher amounts of certain minerals (i.a. Ca, Fe, Cu, Mn) and vitamins (i.a. D, A and B complex) than the muscle tissue (Biesalski, 2005; Cashman, 2012; Florek et al., 2012; Tomović et al., 2011).

The increase in the amount of meat in the carcass, however, does not increase the quality and technological usability of slaughter livestock. Some studies in this area even show a negative correlation between the content of meat in the carcass and its quality (Kapelański et al., 2000; Kortz et al., 2005). Other authors in their studies observed no statistical difference between carcass meatiness and the quality of the meat obtained (Litwińczuk et al., 2005; Zybert et al., 2005). However, there is no data available on the carcass meatiness impact on the quality of the porker's offal.

As such, the aim of the study was to analyse the physicochemical quality of selected pork offal obtained from Puławska pigs that were characterised by different level of meatiness according to the EUROP scale.

Material and methods

Animals

The study was conducted on a group of 50 porkers (gilts) of the Puławska breed whose carcasses were graded into lean meat percentage classes (E≥55% but <60%; U≥50% but <55%; R≥45% but <50%; O≥40% but <45%; P<40%) (according to OJ L 337, 16.12.2008, p. 3, Commission Decision 2005/240/EC of 11 March 2005). Each group was represented by 10 specimens. The porkers came from an individual farm as part of the Conservation Programme for Puławska Pig Genetic Resources. The animals were kept in accordance with the requirements of welfare (Journal of

Laws of 2003, No. 106, item 1002 and Journal of Laws of 2003 No. 167, item 1629) and fed according to current standards (Grela and Skomiał, 2015). Pigs were transported from the farm to the meat plant in accordance with the standards laid down by law (OJ of 2003, No. 185, item 1809). Animals were slaughtered within 2–4 h of transport, in accordance with the company regulations using automatic electrical stunning (250V, 5A, 2.4 s) and exsanguinations in a lying position. The porkers were slaughtered in meat processing plants at 175–180 days of age. The weight of porkers after slaughter averaged 105±2 kg. Carcass meat content was estimated from the measurements of backfat and *m. longissimus dorsi* thickness performed by a certified appraiser with a Sydel CGM device (code: YXX20123.01.T01, distributed by KOMENDER Technologies).

Preparation of samples for laboratory analyses

Pigs' offal was subjected to postmortem veterinary examination. Properly dissected tongue, heart, lungs, liver and kidneys (without connective and adipose tissue) were rinsed under running water to remove blood clots. The cleaned samples were packed into oxygen-permeable containers and transported to the Central Laboratory of Agroecology of the University of Life Sciences in Lublin, where they were stored at +4°C. Samples from the tongue, kidneys, lungs, heart and liver were collected according to the procedures specified by regulations and standards, and then physical characteristics and chemical composition were determined.

Physical characteristics

The hydrogen ion concentration [45 min after slaughter (pH_{45}) and 24 h after slaughter (pH_{24})] was measured using the pH-STAR CPU pH meter equipped with a combination glass electrode for meat pH analysis (Ingenieurbüro R. Matthäus, Nobitz, Germany) and the percentage of free water by a method of Grau and Hamm (1952) in the modification of Pohja and Niinivaara (1957).

Chemical composition

The samples of offal were homogenised and ash percentage was determined by the weighing method (PN-ISO 936:2000); free fat by Soxhlet method (PN-ISO 1444:2000) and protein by Foss-Kjeldahl method (PN-A-04018:1975), using the conversion factor for N of 6.25.

The energy value of each offal, expressed as kJ per 100 g^{-1} fresh tissue, was calculated on the basis of the percentage of crude protein and free fat. The calculations were based on physiological equivalents (1 g protein = 17 kJ, 1 g of fat = 37 kJ) given in the Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011.

The obtained values of physical and chemical traits of the analysed pork offal were compared to the EUROP classes including lean meat as percentage of carcass weight.

Statistical analysis

Pearson's correlation coefficients (r) were calculated for physicochemical characteristics of each offal as well as Spearman's rank correlation coefficients (r_S) between physicochemical parameters of offal and EUROP carcass conformation.

An analysis of variance was performed on the basis of the model:

$$Y_{ij} = \mu + k_i + e_{ij}$$

where:

Y – value of the observed trait;

μ – mean value of a trait;

k_i – fixed effect of the i-class EUROP (i= 1-5);

e_{ij} – random error.

The analyses were performed using the STATISTICA 6.0 software for analysis of data (Statistica version 6.0, StatSoft Inc. 2003, www.statsoft.com). The general linear model procedure for analyses of variance included EUROP class as fixed effects. Tukey's test was applied for the multiple comparison among means, considering P≤0.05 as significant.

Results

Table 1 contains data representing the weight of each pig offal derived from carcasses belonging to the different classes of the EUROP system. Significant relationship between the meatiness and organs' mass was observed. The significant decreases in the weight of offal tongue (r_S = –0.913), kidneys (r_S = –0.778), lungs (r_S = –0.818), heart (r_S = –0.853) and liver (r_S = –0.615) were observed with the increased carcass meatiness.

Table 1. Weight of pork offal depending on the meatiness of the carcass (g)

Meatiness class	Tongue	Kidneys	Lungs	Heart	Liver
	x±sd	x±sd	x±sd	x±sd	x±sd
E	280.5±39.8 a	200.1±23.3 a	1001.0±218.1	390.3±81.1 a	1829.1±412.2 a
U	278.8±35.6 a	202.3±19.5	995.3±222.4 a	391.9±92.5 a	2011.0±358.1 b
R	285.6±33.4	201.7±15.9	965.8±171.5 a	411.8±72.1 a	2301.3±398.2 b
O	297.3±30.2	203.7±22.2	1033.7±245.2	419.7±74.7	2045.2±406.9 b
P	312.1±29.0 b	209.5±25.4 b	1114.1±221.6 b	438.9±74.2 b	2158.4±402.2
r_S	–0.913 *	–0.778*	–0.818*	–0.853*	–0.615*

x – mean value; sd – standard deviation.

Means in columns, marked with different small letters a, b, differ at P≤0.05.

r_S – Spearman's correlation coefficient between offal weight and EUROP carcass conformation. * (P≤0.05).

Table 2. Value of the physical characteristics of the pork offal depending on meatiness of the carcass

Offal	Meatiness class	pH_{45} 1	pH_{24} 2	Free water (%) 3	r		
		x±sd	x±sd	x±sd	1–2	1–3	2–3
Tongue	E	6.34±0.62	5.68±0.51	17.4±2.6	0.551	–0.803*	–0.872*
	U	6.29±0.57 a	5.74±0.68	17.6±2.8 a			
	R	6.30±0.51	5.83±0.37	16.9±2.4			
	O	6.47±0.68 b	5.89±0.75	16.4±2.5 b			
	P	6.38±0.74	5.75±0.68	17.0±2.7			
	r_S	–0.533*	–0.348	0.680*			
Kidneys	E	6.30±0.39	5.97±0.28	13.4±2.1a	0.843*	–0.981*	–0.691*
	U	6.28±0.42 a	5.90±0.35	13.8±1.8a			
	R	6.38±0.28	6.08±0.47	12.6±2.5			
	O	6.42±0.34	6.10±0.54	12.0±1.9			
	P	6.45±0.45 b	6.05±0.52	11.3±2.4 b			
	r_S	–0.935*	–0.481	0.931*			
Lungs	E	6.32±0.41 a	5.88±0.29	18.7±2.0 a	-0.263	–0.918*	–0.120
	U	6.30±0.40 a	5.98±0.32	18.0±2.5 a			
	R	6.43±0.38	5.96±0.37	17.2±3.0			
	O	6.44±0.25	5.94±0.41	17.3±2.8			
	P	6.56±0.51 b	5.90±0.49	16.5±3.2 b			
	r_S	–0.873*	0.435	0.949*			
Heart	E	6.14±0.72	5.71±0.81	15.4±1.9 a	0.894*	0.455	0.378
	U	6.15±0.80	5.70±0.75	16.3±2.0			
	R	6.10±0.64	5.59±0.79	16.6±1.5			
	O	6.18±0.58	5.78±0.64	16.8±1.5			
	P	6.20±0.71	5.84±0.58	17.1±1.6 b			
	r_S	–0.623*	–0.572*	–0.944*			
Liver	E	6.08±0.89 a	5.63±0.94 a	17.9±2.8 a	0.933*	0.845*	0.962*
	U	6.15±0.79	5.67±0.74	18.0±2.7			
	R	6.24±0.75	5.69±0.84	18.1±2.5			
	O	6.34±0.68	5.81±0.78 b	19.4±3.1 b			
	P	6.22±0.98 b	5.69±0.95	18.3±3.5			
	r_S	–0.664*	–0.610*	–0.771*			

x – mean value; sd – standard deviation.

Means in columns within offal, marked with different small letters a,b, differ at P≤0.05.

r – Pearson's correlation coefficient between physical parameters of offal (regardless of conformation class). * (P≤0.05).

r_S – Spearman's correlation coefficient between physical parameter of offal and EUROP carcass conformation. * (P≤0.05).

Table 3. Content of selected chemical compounds in pork offal and energy value depending on meatiness of the carcass

Offal	Meatiness class	Ash (%) 1	Fat (%) 2	Protein (%) 3	Energy value kJ*100 g^{-1} 4	r			
		x±sd	x±sd	x±sd	x	1–2	1–3	1–4	2–3
Tongue	E	0.95±0.11 a	11.83±1.15	15.13±1.06 a	694.92	0.072	–0.511	–0.041	0.203
	U	1.01±0.13	11.16±1.42	14.86±1.11	665.54				
	R	0.98±0.15	11.57±1.25	14.92±1.18	681.73				
	O	0.96±0.15	11.74±1.14	14.79±1.22 b	685.81				
	P	1.10±0.14 b	11.86±1.40	14.81±1.40	690.59				
	r_S	–0.643*	–0.347	0.817*	–0.147				
Kidneys	E	1.11±0.09	3.30±0.54 a	16.34±1.01 a	399.88	0.722*	–0.174	0.752*	–0.587*
	U	1.08±0.10	3.29±0.59 a	16.11±0.98	395.62 a				
	R	1.06±0.08	3.49±0.61	16.19±0.87	404.36				
	O	1.14±0.11	4.32±0.60 b	16.08±0.89 b	433.21 b				
	P	1.11±0.10	3.78±0.78	16.10±1.10	413.56				
	r_S	–0.309	–0.714*	0.747*	–0.628*				
Lungs	E	0.94±0.10 a	4.55±0.85 a	13.19±0.32	392.58 a	0.947*	–0.401	0.932*	–0.357
	U	1.10±0.10	5.35±0.97 a	13.38±0.42	425.41				
	R	1.05±0.09	5.49±1.01	13.54±0.39	433.31				
	O	1.12±0.10	5.89±1.12	13.20±0.35	442.33				
	P	1.18±0.12 b	6.12±1.10 b	12.90±0.40	445.74 b				
	r_S	–0.878*	–0.958*	0.501	–0.917*				
Heart	E	1.01±0.09	2.85±0.87	17.21±0.98	398.02	0.971*	–0.905*	0.935*	–0.897*
	U	0.98±0.10a	2.69±0.58 a	17.25±1.11 a	392.78 a				
	R	1.02±0.10	3.12±0.68 b	17.06±0.57	405.46				
	O	1.06±0.12 b	3.41±0.90 b	16.70±0.64 b	410.07				
	P	1.05±0.11	3.47±1.10 b	16.87±0.54	415.18 b				
	r_S	–0.788*	–0.904*	0.835*	–0.902*				
Liver	E	1.64±0.10 a	5.62±0.98 a	19.73±0.87 a	543.35 a	–0.741*	0.592*	–0.747*	–0.818*
	U	1.67±0.12 a	6.95±1.12 a	19.65±0.75	591.22				
	R	1.32±0.12 b	7.18±1.21	19.67±0.69	600.05				
	O	1.38±0.15 b	7.15±0.95	19.58±1.10 b	597.41				
	P	1.30±0.11 b	8.10±0.99 b	19.60±1.12	632.93 b				
	r_S	0.863*	–0.922*	0.789*	–0.911*				

x – mean value; sd – standard deviation.

Means in columns within offal, marked with different small letters a,b, differ at P≤0.05.

r – Pearson's correlation coefficient between chemical compounds in offal (regardless of conformation class). * (P≤0.05).

r_S – Spearman's correlation coefficient between chemical compound in offal and EUROP carcass conformation. * (P≤0.05).

Another element included in our study was to determine the impact of carcass meatiness on the physical parameters characterising the selected pork offal (Table 2). The lowest average pH_{45} (6.08) and pH_{24} (5.63) was observed in liver of pigs from the class E, while the highest value pH_{45} and pH_{24} was characteristic, respectively, of the lungs of pigs from the class P (6.56) and the kidneys from the class O (6.10). Recorded values of pH_{45} were statistically different within tongue, kidneys, lungs and liver. Significant differences between the averages were observed only in the case of pH_{24} of the liver. The liver pH measured 24 h after slaughter, of which the carcasses were classified as class E, was 0.18 units lower than the pH_{24} of class O liver. An analysis of the Spearman's correlation coefficients has shown that with the increase of meatiness, pH_{45} and pH_{24} decrease in the majority of the analysed offal. The estimated negative values of correlation coefficients proved to be significant in the case of pH_{45} in all analysed offal.

The analysed data (Table 2) have shown that the increase in the carcasses' meatiness had an impact on the increase of the free water content in the tongue ($r_S = 0.680$), kidneys ($r_S = 0.931$) and lungs ($r_S = 0.949$) as well as on the decrease of the water absorption in the heart ($r_S = –0.944$) and liver ($r_S = –0.771$). Moreover, based on the analysis of variance, it has been shown that the value of this indicator characterising the kidneys, lungs and heart of class P carcass was significantly different compared to offal of a high meatiness carcass (class E).

It was found that with the increase of the pH_{45} value, pH_{24} significantly increased in the kidneys ($r = 0.843$), heart ($r = 0.894$) and in the liver ($r = 0.933$). In the case of the tongue, kidneys and liver it was found that increased pH 24 h after slaughter was significantly associated with the increase of the free water in these tissues. All offal, apart from heart, showed a significant correlation between acidity 45 minutes after the slaughter and the content of free water.

The content of selected chemical compounds in pork offal and the energy value depending on the meatiness of the carcass is presented in Table 3. Significant differences in ash content were noted in the tongue, lungs, heart and liver. The liver obtained from carcasses classified as class U and E was characterised by the highest share of ash, just as the class R, O, P liver was characterised by the smallest share. In the case of the tongue, lungs and heart, significant differences occurred also between the extreme meatiness classes E and P (tongue and lungs) and U and O (heart), but ash content in the class with a higher carcass meat content (E, U) was lower than in classes P and O, respectively. In the case of the fat content the offal of class P and O porkers had the highest content compared to high meatiness classes in the lungs, heart, liver and kidneys. Moreover, an analysis of the rank correlation coefficients showed that the carcass meatiness significantly affected the fat content in the kidneys ($r_S = –0.714$), lungs ($r_S = –0.958$), heart ($r_S = –0.904$) and liver ($r_S = –0.922$). The content of protein was significantly different among the various classes of meatiness in all offal except the lungs A significant correlation was observed between the pigs' carcass meatiness and the protein content in tongue ($r_S = 0.817$), kidneys ($r_S = 0.747$), heart ($r_S = 0.835$) and liver ($r_S = 0.789$). Noteworthy is the fact that the offal with the highest protein accumulation is the liver. The content of that chemical component was contained in the range between 19.58 (class O) and 19.73 (class

E). The lowest protein value (from 12.90% – class P to 13.54% – class R) has been exhibited in the lungs. The amount of fat and protein is directly related to the energy value of the offal. The offal with the highest energy (kJ*100 g^{-1}) were the tongue and liver. Depending on carcass meatiness 100 g of this offal contained from 665.54 kJ in tongues (from class U) to 694.92 kJ (from class E) and from 543.35 kJ*100 g^{-1} in liver (from class E) to 632.93 kJ*100 g^{-1} (from class P). Other offal: the heart, lungs, kidneys showed similar parameters of 392.58 (in lung from class E) to 445.74 (in lung from class P). The significant differences were observed between the energy value of offal in the various classes of pigs' carcass meatiness which were marked in kidneys, lungs, heart and liver. According to the analysis of correlation coefficients it was found that the increase of the carcass meatiness significantly reduces the energy value in the lungs (r_S = –0.917), the heart (r_S = –0.902), the liver (r_S = –0.911) and the kidney (r_S = –0.628).

The Pearson correlation coefficients between the chemical parameters in the analysed offal were not significant only in the case of tongue. It was stated that with the increase of the ash value in the kidneys, lungs and heart, the fat content increased (r = 0.722; r = 0.947; and r = 0.971, respectively) as did the energy value of these organs (r = 0.752; r = 0.932; and r = 0.935, respectively). In the case of the heart, it has also been shown that the increase of the ash content and the amount of fat was significantly connected with the reduction of the protein content in this tissue (r = –0.905 and r = –0.897, respectively). In the case of liver, the increase in ash content was paralleled by a significant increase in protein content and a decrease in fat content and energy value of the offal. The decrease in liver fat content significantly increased the protein content.

Discussion

In the meat industry, offal is classified as an 'edible subsidiary slaughter raw material'. Due to its high nutritional value it is most frequently used in food technology for the production of offal sausages (Pisula and Słowiński, 2016). In terms of the food use of offal, it is crucial to pay special attention to its quality. As in the case of meat, the quality of offal should be considered, amongst others, in terms of technological and nutritional quality (PN-A-82023:2000).

The physical parameters of meat are $pH_{45,}$ pH_{24} and water content and these indicators are used as the criterions for assessing the technological value of pork. Measurement of meat pH allows for the monitoring of changes that are occurring *post-mortem*. The difference in pH values measured 45 min and 24 h following slaughter determines the intensity of the glycolytic changes occurring in the raw meat (Sieczkowska et al., 2010).

In all offals a pH decrease the day after slaughter was stated, which coincides with results obtained for calf offal (Florek et al., 2012). The mean values of pH_{45} and pH_{24} that were obtained in the case of the kidney and tongue were comparable with the values obtained in this cited work. Compared to present study, a slightly higher pH was observed in the liver and heart 45 min and 24 h after slaughter.

Acidification of the environment reduces the ability of the protein to bind water, while alkalisation helps to increase its water holding capacity (Dolatowski et al., 2004). The lowest water binding capacity of meat proteins is in pH approx. 5.0, i.e. close to the actomyosin isoelectric point (Litwińczuk et al., 2004). It should be noted that the smaller the logarithm of the hydrogen ion concentration 24 h after slaughter was noted in the sample, the greater was its content of free water, primarily in the tongue ($r = –0.872$) and kidneys ($r = –0.691$). Such a relationship between the pH values, drip loss and colour lightness has also been shown in the works of Barbin et al. (2012) and Prevolnik et al. (2009) on meat tissue.

Litwińczuk et al. (2005) showed that with the carcass meatiness decrease the fat content in *m. longissimus lumborum* was increasing. Similar results were obtained in the present study. Fat, in addition to the role of energy, is also the carrier of taste and smell and its presence shapes the palatability, tenderness and juiciness of the meat. The fat content in the analysed pig offal was about two times higher than that provided in the literature by Seong et al. (2015) and Ockerman and Basu (2004).

The adjusted ratio of fat to the muscle fibres positively affects the organoleptic properties, thus increasing the qualitative assessment of food (Czarniecka-Skubina et al., 2007). Regarding the involvement of protein, there was no significant difference within particular offal. Similar relationships in the case of meat were obtained in the work of Zybert et al. (2005). With regards to the offal, the obtained content of the protein was at a similar level to the content of this nutrient in offal from the Puławska breed pigs of a various genotype RYR1 (Kropiwiec et al., 2015).

The impact of the carcass meatiness on the quality of the raw material for slaughter is not fully clear. In the works of Candek-Potokar et al. (1998) and Koćwin-Podsiadła et al. (2002) it has been shown that the increase of meatiness reduces the quality of the slaughter raw material, while Latorre et al. (2004) state that an increase in the meatiness improves its quality. According to data from the literature, the carcass meatiness should not be combined with the overall quality of the raw material, but with its distinguishing characteristics e.g. acidity, protein and fat content (Zybert et al., 2005). The influence of the meat in the carcass on the analysed traits underlies a high individual variability and can significantly affect, for example, the protein content without causing a significant difference in the fat content.

The changes in the trends of the chemical components that are presented – especially applicable to the liver – emerge due to the fat metabolism occurring in the body as well as its enzyme and storing of minerals role, i.a. iron and zinc (Li et al., 2016; Park et al., 2014; Tomovic et al., 2011).

To summarise the obtained results, it can be concluded that an increase of the meat content in the carcass is significantly associated with a reduction of the offal's weight, a decrease of pH_{45} as well as an increase of the free water content, primarily in the kidney and lungs. In the case of chemical composition, an increase of the meatiness in the carcass was associated with a reduction of fat content in the kidneys, lungs, heart and liver. The liver and the heart were the most susceptible to the effects of the carcass meatiness. With the increase of the carcass meatiness there was a significant change in the liver and heart for the content of the fat (respectively $r_S = –0.922$; $r_S =–0.904$) the ash ($r_S = 0.863$; $r_S =–0.788$), protein ($r_S = 0.789$;

r_S =0.835) and the energy value (r_S = –0.911; r_S =–0.902). Offal from all the studied meatiness classes of the pigs' carcasses was characterised by adequate quality and suitability for processing.

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