

## EFFECT OF SOUS-VIDE HEAT TREATMENT ON THE PHTHALIC ACID ESTERS CONTENT IN MEAT

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### ABSTRACT

The aim of the study was to monitor the migration of the phthalic acid esters dibutyl phthalate (DBP) and di-2-ethylhexyl phthalate (DEHP) from packaging to meat wrapped in plastic when heat treated by sous-vide method. A heat treatment temperature of 80 °C was used for 4 and 8 hours with reheating at 80 °C for 1 hour. The average DBP and DEHP concentrations in meat ranged from 2.24 to 4.66 mg.kg<sup>-1</sup> and 2.29 to 10.35 mg.kg<sup>-1</sup> of the original sample, respectively. The average DBP and DEHP concentrations found in plastic packaging ranged from 3.06 to 6.37 µg.g<sup>-1</sup> and 5.70 to 7.83 µg.g<sup>-1</sup> of plastic, respectively. The average concentrations of DBP in water bath range from 16.25 to 23.38 µg.l<sup>-1</sup>, while the average concentrations of DEHP in water bath were determined between 0.24 and 1.82 µg.l<sup>-1</sup>. The above results were compared with the results measured at sous-vide treatment temperature of 70 °C for 4 hours, 8 hours, and with 1 hour of reheating. The average concentrations of DBP and DEHP in all meat samples exceeded the specific migration limits of both phthalates (0.3 mg.kg<sup>-1</sup> for DBP and 1.5 mg.kg<sup>-1</sup> for DEHP).

**Keywords:** meat; plastic; water; phthalate; heating

### INTRODUCTION

Phthalic acid esters are persistent pollutants, which serve as plasticizers in the industry. The most common are two esters of phthalic acid dibutyl phthalate (DBP) and di-2-ethylhexyl phthalate (DEHP) (Gao and Wen, 2016). DEHP as a plasticizer has been widely used in materials for both food and non-food use, which has led to its expansion into the environment. The plastic components can migrate from the contact materials into food. Migration does not only depend on the type of contact material but also on the composition of the food (pH, fat content, etc.) and the conditions of its processing and storing (time, temperature) (Bradley, Castle and Driffild, 2019). Phthalic acid esters, such as plasticizers, can migrate because they are not firmly bound chemically in plastics (Piotrowska, 2005). In addition, increasing temperature increases the release of plasticizers (Nerín, Acosta and Rubio, 2002). Plastics, many times exposed to heating, in the case of microwave heating of microwave dishes, released more phthalate plasticizers into food than dishes previously unused (Moreira, André and Cardeal, 2014).

The European Union legislation in the Commission Regulation (EU) 10/2011, which deals with food contact materials, sets specific migration limits also for DBP (0.3 mg.kg<sup>-1</sup>) and DEHP (1.5 mg.kg<sup>-1</sup>), where a specific migration limit indicates for a given substance the maximum permitted amount that may pass from the material to the food (Commission Regulation (EU) No. 10/2011).

Esters of phthalic acid have become ubiquitous contaminants because of their wide use and subsequent leaching. They are also problematic because of their high stability and accumulation in the body (Cao, 2010; Chen et al., 2017). They pose a danger to the food chain when irrigating with wastewater (Tan et al., 2016). Their carcinogenic and teratogenic effects have been demonstrated and influence the reproductive capacity of the organism (Velíšek and Hajšlová, 2009).

The sous vide technology is that the food is vacuum packaged in a plastic wrap and heated in a water bath at a combination of temperature and length of heat treatment. Sous vide heat treatment uses temperatures below 100 °C. There are more vitamins preserved in sous vide heat-treated products than with conventional heat treatment (Schellekens, 1996). Vacuum packaged foods are thus heat-treated, cooled, then stored in a cold place and reheated before consumption (Rhodehamel, 1992).

### Scientific hypothesis

We anticipate that plastic packaging intended for wrapping meat for sous vide cooking releases phthalates into meat when different temperature and time modes are used (80 °C for 4 and 8 hours, 70 °C for 4 and 8 hours) and then 1 hour of reheating that simulates reheating before eating meat.

## MATERIAL AND METHODOLOGY

Samples for analysis were prepared in collaboration with the Institute of Gastronomy of the University of Veterinary and Pharmaceutical Sciences Brno. Samples of meat (fresh chilled pork roast, pH 5.44 – 5.58) were purchased in the market network of Brno. The meat was divided into pieces of 150 g, and the pieces were vacuum packed in a packaging designed for heat treatment by sous-vide method. The meat temperature by packaging was at 6 °C. Cryovac® CN300 (Sealed Air Polska Sp. z o.o., Poland) multi-layer cooking bags, thickness 60 µm and with OTR (oxygen transmission rate) 13 cm<sup>3</sup>/m<sup>2</sup>/24 hr/bar at 23 °C and 0 % RH were used for packaging. Subsequently, the samples (n = 6) were heat-treated in a water bath at 80 °C per 4 hours and additional samples (n = 6) at 80 °C per 8 hours. After the heat treatment, half of the samples from both variants of heat treatment were immediately analysed, while the other half of the samples from both variants of heating were stored in the refrigerator for 24 hours and then heat treated in a water bath for 1 hour at 80 °C. Water samples were taken from the water bath before heat treatment and after one hour of heat treatment of the samples from both variants of the heating experiment. Similarly, samples of water from the water bath were taken before and after one hour heat treatment of vacuum-packed samples of meats treated at 70 °C per 4 hours and 70 °C per 8 hours.

In addition, samples of sous vide technologies were prepared for comparison in a similar manner at 70 °C per 4 hours and 70 °C per 8 hours, with repeated heating at 70 °C per 1 hour (Jandlová, Jarošová and Kameník, 2018).

The determination of phthalic acid esters di-2-ethylhexyl phthalate (DEHP) and dibutyl phthalate (DBP) was carried out at the Department of Food Technology of the Mendel University in Brno.

Plastic wraps for meat packaging were first washed in distilled water and dried. For analysis, 10 x 10 cm wraps were taken and then weighed and crushed. Subsequently, they were extracted for 3 days with hexane: dichloromethane (1:1) solvents. The resulting extract was evaporated using a vacuum rotary evaporator, transferred to hexane and subsequently, in the absence of turbidity, transferred to acetonitrile for HPLC determination. If turbidity was present, the sample was centrifuged and the hexane portion was then transferred to acetonitrile (Gajdůšková, Jarošová and Ulrich, 1996).

Meat samples were homogenized and about 50 g of the sample was weighed for analysis; the sample was frozen and lyophilized. Fat was extracted from the lyophilized sample with hexane: acetone (1: 1), the solvents were then evaporated on a vacuum rotary evaporator. Gel permeation chromatography separated the phthalate fraction which was clarified with sulphuric acid and transferred to vials with acetonitrile for HPLC determination (Jarošová et al., 1999).

Water from the water bath was extracted three times with dichloromethane in a separatory funnel. The combined extracts were evaporated on a rotary evaporator and transferred to the vials with acetonitrile for HPLC determination (Jarošová et al., 1999). Measurement was performed on HPLC with UV detection at a wavelength of 224 nm, acetonitrile was used as the mobile phase.

Measurement was performed with HPLC system under UV detection at 224 nm, with acetonitrile as the mobile phase, and Zorbax Eclipse C8 column. The evaluation was done using the Data Analysis program (Agilent Technologie).

## Statistic analysis

The data was processed using Microsoft Excel (Microsoft Corporation, USA) and Statistica 12 (StatSoft, USA) software. The Shapiro-Wilk's test was used for testing the normality of data and the Grubbs test was used to detect outliers ( $\alpha = 0.05$ ). Furthermore, the independent samples t-test was run to determine the conformity of the means ( $\alpha = 0.05$ ).

## RESULTS AND DISCUSSION

Table 1, Table 2 and Table 3 show concentrations of phthalic acid esters (DBP a DEHP) in meat, plastic packaging, and water from the water bath.

The average concentration of DBP and DEHP (Table 1) was  $2.30 \pm 0.60$  and  $6.17 \pm 2.91$  mg.kg<sup>-1</sup> respectively in meat samples heat treated at 70 °C per 4 hours, and  $2.36 \pm 1.58$  and  $14.78 \pm 10.19$  mg.kg<sup>-1</sup> respectively when heat treated at 70 °C per 8 hours. The results show that a longer period (8 hours) of heat treatment resulted in a higher migration of both phthalates from the packaging to meat.

The average concentration of DBP and DEHP was  $2.89 \pm 1.94$  and  $6.95 \pm 2.95$  mg.kg<sup>-1</sup> respectively in meat samples heat treated at 70 °C per 4 hours + 70 °C per 1 hour and  $3.14 \pm 0.90$  and  $5.04 \pm 2.18$  mg.kg<sup>-1</sup> respectively when heat treated at 70 °C per 8 hours + 70 °C per 1 hour. The results show that for DBP a longer period (8 hours) of heat treatment resulted in a higher concentration in meat.

The average concentration of DBP and DEHP was  $4.60 \pm 1.06$  and  $10.35 \pm 2.32$  mg.kg<sup>-1</sup> respectively in meat samples heat treated at 80 °C per 4 hours and  $3.43 \pm 0.69$  and  $3.82 \pm 0.95$  mg.kg<sup>-1</sup> respectively when heat treated at 80 °C per 8 hours. The results show that over a longer period of time the two phthalates decreased.

The average concentration of DBP and DEHP was  $2.24 \pm 0.24$  and  $2.91 \pm 0.59$  mg.kg<sup>-1</sup> respectively in meat samples heat treated at 80 °C per 4 hours + 80 °C per 1 hour and  $4.66 \pm 1.87$  and  $5.08 \pm 0.96$  mg.kg<sup>-1</sup> respectively when heat treated at 80 °C per 8 hours + 80 °C per 1 hour. The results show that for both phthalates a longer (8 hours) heat treatment resulted in higher concentrations in meat.

The average concentration of DBP and DEHP was  $2.30 \pm 0.60$  and  $6.17 \pm 2.91$  mg.kg<sup>-1</sup> respectively in meat samples heat treated at 70 °C per 4 hours and  $4.60 \pm 1.06$  and  $10.35 \pm 2.32$  mg.kg<sup>-1</sup> respectively when heat treated at 80 °C per 4 hours. The results show that at higher temperature (80 °C) of heat treatment there was a higher migration of both phthalates from the packaging into meat.

The average concentration of DBP and DEHP was  $2.89 \pm 1.94$  and  $6.95 \pm 2.95$  mg.kg<sup>-1</sup> respectively in meat samples heat treated at 70 °C per 4 hours + 70 °C per 1 hour and  $2.24 \pm 0.24$  and  $2.91 \pm 0.59$  mg.kg<sup>-1</sup> respectively when heat treated at 80 °C per 4 hours + 80 °C per 1 hour. The results show that the higher temperature of heat treatment resulted in a decrease in the concentration of both phthalates in meat.

**Table 1** The average concentrations and standard deviation ( $\bar{x} \pm SD$ ) of dibutyl phthalate (DBP) and di-2-ethylhexyl phthalate (DEHP) in mg.kg<sup>-1</sup> of original mass in the samples of meat heat treated at 70 °C (Jandlová, Jarošová and Kameník, 2018) or 80 °C for 4 or 8 hours with the sous vide technology and then heat treated for 1 hour at 70 °C or 80 °C.

Heat-treated samples of meat	DBP (mg.kg <sup>-1</sup> ± SD)	DEHP (mg.kg <sup>-1</sup> ± SD)
70 °C for 4 hours	2.30 ±0.60	6.17 ±2.91
80 °C for 4 hours	4.60 ±1.06	10.35 ±2.32
70 °C for 4 hours + 70 °C for 1 hour	2.89 ±1.94	6.95 ±2.95
80 °C for 4 hours + 80 °C for 1 hour	2.24 ±0.24	2.91 ±0.59
70 °C for 8 hours	2.36 ±1.58	14.78 ±10.19
80 °C for 8 hours	3.43 ±0.69	3.82 ±0.95
70 °C for 8 hours + 70 °C for 1 hour	3.14 ±0.90	5.04 ±2.18
80 °C for 8 hours + 80 °C for 1 hours	4.66 ±1.87	5.08 ±0.96

Note: Each value represents the average of three determinations of meat samples.

**Table 2** The average concentrations and standard deviation ( $\bar{x} \pm SD$ ) of dibutyl phthalate (DBP) and di-2-ethylhexyl phthalate (DEHP) in µg.dm<sup>-2</sup> and µg.g<sup>-1</sup> of packaging in the samples of plastic packaging used for vacuum packaging of meat heat treated at 70 °C (Jandlová, Jarošová and Kameník, 2018) or 80 °C for 4 or 8 hours with the sous vide technology and then heat treated for 1 hour at 70 °C or 80 °C.

Samples of meat plastic packaging – heat treated	DBP (µg.dm <sup>-2</sup> ± SD)	DEHP (µg.dm <sup>-2</sup> ± SD)	DBP (µg.g <sup>-1</sup> ± SD)	DEHP (µg.g <sup>-1</sup> ± SD)
70 °C for 4 hours	4.01 ±0.32	3.40 ±1.11	4.75 ±0.40	4.03 ±1.35
80 °C for 4 hours	3.73 ±0.79	7.99 ±0.64	3.06 ±0.65	6.56 ±0.54
70 °C for 4 hours + 70 °C for 1 hour	4.35 ±0.81	5.81 ±0.99	4.87 ±0.91	6.50 ±1.12
80 °C for 4 hours + 80 °C for 1 hour	4.42 ±0.15	6.70 ±0.16	3.77 ±0.21	5.70 ±0.14
70 °C for 8 hours	2.18 ±0.24	1.70 ±0.30	2.43 ±0.42	1.91 ±0.45
80 °C for 8 hours	7.28 ±4.15	8.34 ±0.77	6.37 ±4.04	7.02 ±0.29
70 °C for 8 hours + 70 °C for 1 hour	2.42 ±0.14	4.51 ±0.60	2.65 ±0.16	4.95 ±0.78
80 °C for 8 hours + 80 °C for 1 hour	6.27 ±1.10	9.48 ±0.17	5.18 ±0.96	7.83 ±0.20

Note: Each value represents the average of three determinations of packaging samples.

**Table 3** The average concentrations and standard deviation ( $\bar{x} \pm SD$ ) of dibutyl phthalate (DBP) and di-2-ethylhexyl phthalate (DEHP) in µg.l<sup>-1</sup> in the samples of water from water baths used for reheating the meat samples (previously treated with the sous vide technology) for 1 hour at 70 °C or 80 °C, taken before and after the heat treatment.

Samples of water from water baths used for meat samples reheating	Sampling – reheating	DBP (µg.L <sup>-1</sup> ± SD)	DEHP (µg.L <sup>-1</sup> ± SD)
70 °C for 1 hour (meat samples heat treated at 70 °C for 4 hours)	Before	16.25 ±0.84	1.82 ±0.07
	After	23.38 ±2.10	0.24 ±0.20
70 °C for 1 hour (meat samples heat treated at 70 °C for 8 hours)	Before	23.38 ±2.10	0.24 ±0.20
	After	18.78 ±4.71	0.83 ±0.55
80 °C for 1 hour (meat samples heat treated at 80 °C for 4 hours)	Before	18.78 ±4.71	0.83 ±0.55
	After	20.64 ±2.29	0.90 ±0.57
80 °C for 1 hour (meat samples heat treated at 80 °C for 8 hours)	Before	20.64 ±2.29	0.90 ±0.57
	After	22.49 ±8.25	1.16 ±1.51

Note: Each value represents the average of three determinations of water samples.

The average concentration of DBP and DEHP was  $2.36 \pm 1.58$  and  $14.78 \pm 10.19$  mg.kg<sup>-1</sup> respectively in meat samples heat treated at 70 °C/8 hours and  $3.43 \pm 0.69$  and  $3.82 \pm 0.95$  mg.kg<sup>-1</sup> respectively when heat treated at 80 °C/8 hours. The results show that over a longer period (8 hours) of heat treatment there was a decrease of DEHP, while DBP slightly increased.

The average concentration of DBP and DEHP was  $3.14 \pm 0.90$  and  $5.04 \pm 2.18$  mg.kg<sup>-1</sup> respectively in meat samples heat treated at 70 °C per 8 hours + 70 °C per 1 hour and  $4.66 \pm 1.87$  and  $5.08 \pm 0.96$  mg.kg<sup>-1</sup> respectively when heat treated at 80 °C per 8 hours + 80 °C per 1 hour. The results show that the higher temperature of heat treatment resulted in a higher concentration of both phthalates in meat.

At the temperature variant of 70 °C, with increasing time (from 4 to 8 hours) the phthalate concentration in meat increased and decreased at 80 °C. Additional heating for 1 hour resulted in a fall of phthalates in samples heat treated over 4 hours at a higher temperature (80 °C). After comparing mean values for independent samples using a t-test, for DBP and DEHP concentrations in meat products the mean values were equal for all samples ( $p > 0.05$ ) – always variants of different temperatures but same heating times were compared.

Even studies of other authors (**Zhang and Guo, 2009; Xue et al., 2010**) have shown the presence of phthalates in packaging materials and their migration from packaging to food. **Zhang and Guo (2009)** found that the migration of DEHP from PVC foil into meat increased with the increasing temperature and time. Maximum DEHP migration was at 90 °C and 30 minutes of action ( $1961.92$  mg.kg<sup>-1</sup>;  $75.12$  mg.dm<sup>-2</sup>). The overall migration limit ( $60$  mg.kg<sup>-1</sup>;  $10$  mg.dm<sup>-2</sup>) was exceeded in all the time and temperature combinations monitored, except for the combination of 10 °C and <41 hours where migration was not observed. In the light of the **Commission Regulation (EU) 10/2011** dealing with plastic food contact materials, given the specific migration limits for DBP ( $0.3$  mg.kg<sup>-1</sup>) and DEHP ( $1.5$  mg.kg<sup>-1</sup>), which set a maximum allowable quantity that may pass from materials to food, all samples exceeded the values indicated in legislation.

In our study, the average DBP and DEHP concentrations in all meat samples exceeded the specific migration limits. The average DBP concentrations for plastic packaging at the temperature variant of 70 °C and 80 °C ranged from 2.43 to 4.87 and from 3.06 to 6.37 µg.g<sup>-1</sup> respectively of the packaging.

The average DEHP concentrations for plastic packaging at the temperature variant of 70 °C and 80 °C ranged from 1.91 to 6.50 and from 5.70 to 7.83 µg.g<sup>-1</sup> respectively of the plastic packaging.

At the temperature variant of 70 °C, with increasing time of heat treatment from 4 to 8 hours the phthalate concentration in packaging decreased and increased at 80 °C. Additional heating of the packaged meat samples in water bath for 1 hour resulted in a growth of phthalates in samples of packaging heat treated at 70 °C.

After comparing mean values for independent samples using a t-test, for DBP concentrations in µg.dm<sup>-2</sup> for plastic packaging the mean values were equal for all samples ( $p > 0.05$ ), except for the variant of 70 °C per 8 hours + 1 hour versus 80 °C per 8 hours + 1 hour ( $p < 0.05$ ). After

comparing mean values for independent samples using a t-test, for DEHP concentrations in µg.dm<sup>-2</sup> for plastic packaging, only mean values for the variant 70 °C per 4 hours + 1 hour versus 80 °C per 4 hours + 1 hour were equal ( $p > 0.05$ ).

After comparing mean values for independent samples using a t-test, for DBP concentrations in µg.g<sup>-1</sup> for plastic packaging the mean values were equal for all samples ( $p > 0.05$ ), except for the variants of 70 °C per 4 hours versus 80 °C per 4 hours ( $p < 0.05$ ) and 70 °C per 8 hours + 1 hour versus 80 °C per 8 hours + 1 hour ( $p < 0.05$ ). After comparing mean values for independent samples using a t-test, for DEHP concentrations in µg.g<sup>-1</sup> for plastic packaging, the mean values were equal for all samples ( $p > 0.05$ ), except for the variants of 70 °C per 8 hours versus 80 °C per 8 hours ( $p > 0.05$ ) and 70 °C per 8 hours + 1 hour versus 80 °C per 8 hours + 1 hour ( $p > 0.05$ ).

In the t-test always variants of different temperatures but same heating times were compared.

**Nerín, Acosta and Rubio (2002)** states that the decomposition of polymer chain and additives occurs with increasing temperature, and additives, including phthalic acid esters, can be released from plastics.

**Rastkari et al. (2017)** studied the effect of storage time, temperature and bottle type on the migration of phthalates from packaging materials to fruit drinks. Drinks were filled into polyethylene terephthalate (PET) and high-density polyethylene (HDPE) bottles. The analysis performed before and after 2, 4 and 6 months of storage showed that the migration of DEP (diethyl phthalate), DEHP and DBP from packaging materials into aqueous solutions increased with the increasing acidity.

The average concentration of DBP and DEHP in samples of water from water baths before the heat treatment ranged from 16.25 to 23.38 and 0.24 to 1.82 µg.l<sup>-1</sup> respectively. After reheating, the concentration of DBP and DEHP was from 18.78 to 23.38 and 0.24 to 1.16 µg.l<sup>-1</sup> respectively. In most cases, the concentration of both phthalates after heating in water bath samples increased, except for DBP at 70 °C per 1 hour of heat treatment (meat sample heat treated at 70 °C per 8 hours) and for DEHP at 70 °C per 1 hour of water heating (meat sample heat treated at 70 °C per 4 hours). Evidently, the phthalic acid esters from plastic packaging were released into water.

After the t-test of the mean values for independent samples, where the same samples of water were compared before and after the heating, mean values of both DBP and DEHP concentrations were equal ( $p > 0.05$ ), except for the variant before and after the heating at 70 °C per 1 hour of samples heat treated at 70 °C per 4 hours ( $p < 0.05$ ).

Study by **Xu et al. (2010)** has dealt with PAE migration from plastic packaging into mineral water and kitchen oil. Oil was a better medium for the migration of phthalates, due to its lipophilic nature. It was also found that, with increasing temperature and contact time with the plastic material, the migration of phthalic acid esters was more significant.

**Simoneau, Van den Eede and Valzacchi (2012)** examined the migration of phthalate from baby bottles ( $n = 277$ ) under the conditions of hot filling for 2 hours at 70 °C and found migration levels of diisobutyl phthalate (DIBP) and dibutyl phthalate (DBP) from 50 to

150 µg.kg<sup>-1</sup>, while DEHP exhibited relatively lower levels of migration (25 to 50 µg.kg<sup>-1</sup>).

The migration of phthalates from plastic bottles of four bottled water labels was monitored by **Vazquez et al. (2017)**. Samples were stored for 70 days at three different temperatures (8 +/-2 °C, 22 - 25 °C, 35 +/-1 °C). Dibutyl phthalate (DBP), benzyl butyl phthalate (BBP) and di-2-ethylhexyl phthalate (DEHP) have been identified in all four bottled water labels. The most common phthalate in all the samples studied was DEHP.

In a previous study by **Jandlová, Jarošová and Kameník (2017)**, the average concentrations of phthalic acid esters in the original raw meat mass and in the original plastic non-heated packaging have been reported, which we have also used for this study. In raw unpackaged meat the average concentration of DBP and DEHP was determined to be 7.56 and 13.82 mg.kg<sup>-1</sup> respectively of the original mass. In the original plastic non-heated packaging the average concentration of DBP and DEHP was 22.47 and 11.76 µg.g<sup>-1</sup> respectively of the plastic. If we compare the average concentrations of both phthalic acid esters found in the meat products heat treated with the sous vide technology at 70 °C and 80 °C with the average concentrations found in raw meat, the average concentrations of DBP and DEHP in heat treated meats were lower than in the raw meat, except for the variant of 70 °C per 8 hours, where the average DEHP concentration was higher in heat treated meat than in raw meat. If we compare the average concentrations of both phthalic acid esters in the original plastic packaging with the plastic packaging exposed to heating in water bath at 70 °C and 80 °C, the average concentrations of both phthalic acid esters were lower in the plastic packaging exposed to heating in water bath against the original non-heated plastic packaging.

## CONCLUSION

The average concentrations of DBP and DEHP in sous-vide-treated meat are higher than the specific migration limits (0.3 mg.kg<sup>-1</sup> for DBP and 1.5 mg.kg<sup>-1</sup> for DEHP) laid down in the Commission Regulation (EU) No 10/2011.

The assumed hypothesis that the concentrations of phthalic acid esters will decrease with the heat treatment time and higher temperature has not been definitely confirmed.

In our study, we compared the mean values of concentrations by t-test ( $\alpha = 0.05$ ).

Under sous-vide treatment at 70 °C per 4 hours, average concentrations of both phthalates in meat were lower than at 70 °C per 8 hours. When comparing the heat treatment at 80 °C per 4 hours and 80 °C per 8 hours, the average concentrations of both phthalates in meat decreased with a longer heat treatment time. Additional heating for 1 hour resulted in a decrease of both phthalates in samples of meat heat treated for 4 hours at higher temperature (80 °C). Our examined temperature and time variants of meat heating with sous vide technology suggest that the most suitable variant of meat sous-vide treatment is at 80 °C per 4 hours + 80 °C per 1 hour, even if this variant also constitutes exceeding the specific migration limits.

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