

# THE EFFECTS OF SPRAY-CHILLING ASSOCIATED TO CONVENTIONAL CHILLING ON MASS LOSS, BACTERIOLOGICAL AND PHYSICO-CHEMICAL QUALITY OF BEEF CARCASS

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## SUMMARY

The purpose of this study was to verify the effect of conventional air chilling associated to intermittent spray-chilling treatment, on weight loss, physico-chemical and bacteriological quality of beef carcasses. Two plants of commercial beef slaughterhouse located in Goiânia and fiscalized by the Federal Inspection Service were used to develop the research. The spray-chilling treatment was accomplished in an intermittent way, commanded by a controlled logical program, with cycles of 90 seconds, in intervals of 30 minutes, during the first 4 hours of the chilling process. Physico-chemical and bacteriological analysis were made in spray-chilled water and carcasses samples,

according to recommendation of the effective legislation. The average values of carcasses weight loss of treatment group were lower to the ones verified for the control group, in both plants, A and B, ( $P < 0,001$ ), showing a high economic potential. As a conclusion of physico-chemical and bacteriological analysis results of water and meat samples, it is clear that the technology of chilling beef carcasses in the conventional system associated to spraying did not interfere in the quality of meat, and it can become an analysis object on part of official organs for sanitary regulation and fiscalization, for its definitive adoption.

**KEY WORDS:** Spray-chilling, shrinkage, beef carcass.

## RESUMO

### EFEITOS DA ASPERSÃO ASSOCIADA AO PROCESSO DE REFRIGERAÇÃO CONVENCIONAL SOBRE A QUEBRA DE PESO, QUALIDADE BACTERIOLÓGICA E FÍSICO-QUÍMICA DE CARCAÇAS BOVINAS

O presente ensaio teve como objetivo verificar o efeito do sistema convencional de refrigeração associado à aspersão intermitente de água gelada sobre as meias-carcaças bovinas, na quebra de peso, qualidade físico-química e bacteriológica da carne. Foram utilizadas duas plantas de abate de bovinos localizadas na grande Goiânia e fiscalizadas pelo Serviço da Inspeção Federal. A aspersão foi realizada de forma intermitente, comandada por um programa lógico controlado, em ciclos de 90 segundos, em intervalos de 30 minutos, durante as primeiras quatro horas do processo de refrigeração. Realizaram-se análises bacteriológicas e físico-químicas em amostras das meias-carcaças e

da água aspergida, conforme recomendação da legislação vigente. Os valores médios de quebra de peso das meias-carcaças do grupo tratamento foram inferiores aos verificados para o grupo controle, na unidades de abate A e B ( $p < 0,001$ ), indicando elevado potencial econômico. Da análise dos resultados bacteriológicos e físico-químicos das amostras de carne e água depreende-se que a tecnologia de refrigeração de meias-carcaças bovinas pelo sistema convencional associado à aspersão não interferiu na qualidade da carne e pode se constituir em objeto de análise por parte dos órgãos oficiais de regulamentação e fiscalização, visando sua adoção definitiva.

**PALAVRAS-CHAVE:** Aspersão de carcaça, quebra de peso, carcaça bovina.

## INTRODUCTION

The main reasons for chilling beef carcasses quickly are the restriction of bacterial growth and the need of meat industry to obey the established conditions for chilling.

WIRTH et al. (1981) indicated the following techniques of conventional air chilling for carcasses: the temperature of chilling room must be between  $-1^{\circ}\text{C}$  and  $+1^{\circ}\text{C}$ , the relative air humidity between 85 and 90%, air velocity between 1 and 4 m/s, chilling time between 18 and 24 hours, and deep muscle temperature at  $+4^{\circ}\text{C}$ . The authors also indicated that for maintenance of chilling conditions, the ambient temperature in the chilling room should be from  $-1$  to  $+2^{\circ}\text{C}$ , the relative air humidity of the air from 85 to 95% and the air velocity from 0.1 to 0.3 m/s.

In South Africa, the regulation organs do not stipulate the temperature after the carcasses are chilled. However, it determines a minimum post-mortem time chilling of 16 hours, under specific ambient temperature and air velocity. The air temperature in the beginning of the process cannot exceed  $7^{\circ}\text{C}$ , and in the terminal part of the chilling process, it should be maintained between  $-1$  and  $+2^{\circ}\text{C}$ . Besides, the medium air velocity on the carcasses should be maintained above 0.75 m/s (STRYDOM & BUYS, 1995).

In Brazil, the newsletter 224/2001 of the Control of International Trade Division, of the Inspection of Animal Origin Products Department, of the Agriculture and Provisioning Ministry deals with the conventional air chilling in the following way: the maturation process consists of submitting the carcasses to an ambient temperature above  $+2^{\circ}\text{C}$ , for a minimum period of 24 hours, in agreement to the Directive 93/402 of the European Economical Community (BRASIL, 2001).

During the air conventional chilling process of carcasses in the industry, some alterations of physical, chemical or biological nature can occur. The evaporation weight loss phenomenon, that can overcome 2.5%, builds up one of the most important modifications for the industry and distributors, due to its economical aspect (PARDI et al., 1993).

The spraying of carcasses in industrial plants, during the conventional air chilling process, has the larger purpose of decreasing weight loss. According to HEITTER (1975) the clor-chill system, introduced by the Swift and Company, involves the intermittent chlorinated water spraying on the carcass in predetermined intervals, during the normal cycle of chilling. The use of this system intends to reduce the weight loss due to evaporation, and bacterial contamination.

KASTNER (1981) informed that bovine carcasses protected by cotton or shrouded and chilled overnight by the conventional system, lose from 0.75 to 2.0% of weight. According to ALLEN et al. (1987) and JONES et al. (1988) the carcasses spraying during the conventional air chilling reduces the weight loss due to the evaporation process in 0.5 to 1.5% during the first 24 hours post-mortem.

In agreement to JONES and ROBERTSON (1988) the spraying or the water application over the beef carcasses in intermittent periods, was adopted by most of North America abattoir plants, with the purpose of reducing weight loss during the period of chilling.

Without committing legal aspects, the spraying during the chilling was adopted in 1987 by the major part of commercial beef slaughterhouse in the United States, in order to reduce carcasses weight loss due to high air velocity, adopted in the conventional air chilling process (STRYDOM & BUYS, 1995).

JOHNSON et al. (1988) affirmed that the intermittent spraying of cold water in beef carcasses from 3 to 8 hours, during chilling, became norm in the United States in commercial beef slaughterhouse. According to the authors, the United States Agriculture Department determinates that the carcasses weight after chilling cannot exceed the weight of the hot carcass before the pre-washing. The process of spraying beef carcasses is regulated by the Directive 6330.1, of 5/26/1993, of FSIS - Food Safety and Inspection Service (FSIS, 2002).

JONES and ROBERTSON (1988) apud GREER et al. (1990) informed that the spraying constitutes an approved, practical and economical way in which the Canadian meat industry could

minimize evaporative weight losses, without compromising the carcass quality.

GREER et al. (1990) reported that the weight loss of beef carcasses chilled by the conventional process, in the first 24 hours, it was significantly reduced ( $P < 0,001$ ) from 1.33 to 0.28%, when the spraying was associated to conventional air chilling.

In relation to the bacteriological quality of spray-chilled carcasses, GREER and DILTS (1988) informed that in some circumstances the spray-chilling lightly reduced the bacterial count. GREER and JONES (1997) observed that in comparison to conventional air chilling, spray-chilled carcasses by 4, 8, 12 or 16 hours did not present effects on anaerobic bacteria growth in *longissimus thoracis* muscle stored for 2, 16, 30 or 44 days at +2°C and under vacuum package conditions.

GREER et al. (1990) studying the effect of spray-chilling on bacteriological quality and shelf life of carcasses and beef cuts, verified reduction in the initial bacterial load.

GREER and JONES (1997) verifying the quality and the bacteriological consequences of the spray-chilling on the beef carcasses, affirmed that, except for the color, the meat quality was not affected by the process, that lasted from 4 to 16 hours. Thus, marbling score, loin eye area, pH after 24 hours, moisture percentage, sarcomere lengths and the shear values were not different ( $P > 0,05$ ) for spray-chilled and conventional chilled carcasses.

Considering the importance of this theme, the inexistence of national data bank that could support a decision process of the regulation and fiscalization organs, as well as, from the businessmen of the area in the Goiás State, about the installation of spraying system of carcasses during the chilling, the present assay intended to verify the effect of the conventional air chilling system associated to the spraying beef carcasses on the weight loss and in the physico-chemical and bacteriological quality of the carcasses.

## MATERIAL AND METHODS

The experiment was developed by the Centro de Pesquisa em Alimentos – CPA – of the Escola de Veterinária da Universidade Federal de Goiás, in two different units of commercial beef

slaughterhouse located in Goiânia city, both fiscalized by the Federal Inspection Service–FIS. Two different establishments were used to reduce possible effects linked to the individual characteristics of slaughter.

In the period from 3/21 to 4/25/2000, the experiment took place in the unit A, and, from 3/7 to 4/26/2001, in unit B. The experiments were inspected in the commercial beef slaughterhouse by the FIS.

### Spray-chilling system

A group of nail-parallel PVC pipes was used in the chilling room, with beaks adapted to promote spraying of water previously chilled to a maximum temperature of +2°C on the carcasses sides.

The spraying was developed in an intermittent way, during the conventional air chilling process, commanded by a controlled logical program, in cycles of 90 seconds, in intervals of 30 minutes, for 4 hours, with counting of time started when the chilling room was closed.

## CARCASS ANALYSIS

Carcasses were randomly sampled, being 61 side-carcasses for the treatment group and 61 for control group in unit A, and 72 for each group in unit B. The carcasses were submitted to sampling in alternate days, being 10 of each group per day.

The weighing of hot carcass sides was made in scale with sensibility of 100g, used in the abattoir normal flux in unit A and 500g in unit B. The carcass sides were again weighted after the process of chilling in temperatures of approximately 0°C ± 1°C, for 24 hours.

Samples for bacteriological analyses were obtained by the smear swab technique in surface, using metallic cast of 100 cm<sup>2</sup>, applied in three different points at the carcass side, outside round, loin, and shoulder, in unit A and, in only one point of the carcass side, outside round, in unit B. In unit A, the three points constituted an only sample.

The physico-chemical analysis was made from samples taken off portions of diaphragmatic muscle tissue, the thin skirt, of the hot carcass side, and after chilling. The taken portions were conditioned properly in identified individual plastic bags. So, they were conditioned immediately in cooler boxes containing recyclable ice, and sent directly to the laboratories of CPA.

#### PHYSICO-CHEMICAL ANALYSIS DETERMINATION OF THE pH

The determination of the pH was made with a pHmeter HANNA, model HI 8314, through introduction of the electrode in a depth of approximately 3 cm, in the muscular portion of the *longissimus dorsi* of the carcass side, hot and chilled, in the region of the 6th lumbar vertebra. Moments before the use, the equipment was calibrated with buffer solutions of pH 7.0 and 4.0.

#### DETERMINATION OF WATER ACTIVITY

Samples of approximately 5g were taken off the portion of the diaphragmatic muscle tissue of the carcass sides, hot and chilled. These samples were analyzed for determination of water activity using the equipment THERMOCONSTANTER, model TH 200, of NOVASINA, according to the manufacturer's recommendations.

#### DETERMINATION OF MOISTURE

Moisture of the samples taken off the carcass sides, hot and chilled, was determined according to the methodology described in *Métodos analíticos oficiais para controle de produtos de origem animal e seus ingredientes* (BRASIL, 1981).

#### BACTERIOLOGICAL ANALYSIS

The swabs employed in the collection of samples for the smear technique in surface were placed in tubes containing 5mL of peptone water 0.1%, and led to the laboratory of microbiology of CPA.

With the intention of monitoring both groups of the experiment, control and treatment, in relation to the indicative microorganisms, the following analyses were made: Count of aerobic psychrotrophic microorganisms, Determination of the Most Probable Number (MPN) of fecal coliforms and Standard Plate Count of aerobic mesophilic microorganisms (SPC). The SPC was made in 14 samples from unit A, and in all samples from unit B.

All the bacteriological analyses were made based on methodology described in *Métodos de*

*análise microbiológica para alimentos* (BRASIL, 1999).

#### WATER ANALYSIS

Water samples were taken in asepsis condition, in alternate days, according to the sampling of the carcasses, 6 water samples of the aspersion system in unit A, and 7 in unit B. The system was switched on and, after the approximate time of one minute, the samples were taken in sterilized individual flasks, close to the spraying beaks, and sent directly, under condition of refrigeration, to the laboratory of CPA.

#### PHYSICO-CHEMICAL ANALYSIS TEMPERATURE OF SPRAYED WATER

The temperature of the water taken in the exit of the spraying beak, was evaluated using an Inconterm thermometer, with graduation from -10°C to +100°C, in unit A; and, in unit B, a Digital LCD Multisystem thermometer, with graduation from -50 °C to +150 °C.

#### FREE CHLORINE DOSAGE

In this analysis, 6 samples of water from the spraying system were used at unit A, and 5 samples from unit B. The employed method was the colorimetric process of O-toluidin, and the reading was made in a spectrophotometer at 465 nm, according to *Métodos analíticos oficiais para controle de produtos de origem animal e seus ingredientes* (BRASIL, 1981).

#### BACTERIOLOGICAL ANALYSIS

The SPC and the MPN of total and fecal coliforms were made, according to APHA (1995).

#### STATISTICAL ANALYSIS

The average values and standard error were calculated for the studied variables, except the values of the average corresponding to the physico-chemical analysis of water. In the comparison of the averages, it was used the Student's *t* test, and for some

variables, the logarithmic transformation of the original data took place.

## RESULTS AND DISCUSSION

In Table 1, the average and standard errors values, that were obtained for the variables weight, pH, water activity and moisture, in the commercial beef slaughterhouse units A and B are distributed. It is noticed that in the units A and B, the averages of the variables weight and pH, in control and treatment groups, did not present significant difference ( $P > 0,05$ ). On the other hand, in the two units, the averages obtained for moisture, were significantly different to each other ( $P < 0,05$ ), being higher for

the treatment group. This was already waited, having in mind that the muscular, fat and conjunctive tissues lost less water by the evaporative process. Complementary studies are necessary, but the moisture seems to be a good pattern of the control of beef carcasses spray-chilling process.

In relation to water activity, the average values obtained for the two groups of unit A, although the likeness, showed significant difference ( $P < 0,05$ ). The average values obtained for the two groups of unit B, did not present significant difference ( $P > 0,05$ ). It was not found in the consulted literature, studies that could support the discussion of the presented results.

**TABLE 1.** Distribution of average values obtained for the variables weight, pH, water activity and moisture, in the units A and B.

Variables	Parameters	Unit A				Unit B			
		Control		Treatment		Control		Treatment	
		HC <sup>1</sup>	CC <sup>2</sup>	HC	CC	HC	CC	HC	CC
Weight (kg)	Average	125.92	124.17 <sup>a</sup>	125.65	124.50 <sup>a</sup>	121.90	120.01 <sup>a</sup>	121.34	120.17 <sup>a</sup>
	Standard Error	1.53	1.48	1.90	1.48	1.82	1.79	1.77	1.74
pH	Average	6.72	5.93 <sup>a</sup>	6.68	5.92 <sup>a</sup>	6.63	5.79 <sup>a</sup>	6.67	5.75 <sup>a</sup>
	Standard Error	0.03	0.04	0.03	0.04	0.03	0.03	0.04	0.02
Water Activity	Average	0.97	0.96 <sup>a</sup>	0.97	0.97 <sup>b</sup>	0.95	0.95 <sup>a</sup>	0.95	0.95 <sup>a</sup>
	Standard Error	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Moisture (%)	Average	77.65	73.70 <sup>a</sup>	76.78	76.17 <sup>b</sup>	74.39	71.32 <sup>a</sup>	74.54	73.64 <sup>b</sup>
	Standard Error	0.25	0.38	0.32	0.39	0.21	0.40	0.28	0.30

<sup>1</sup> HC: Hot Carcasses

<sup>2</sup> CC: Chilled Carcasses

<sup>a</sup> Average followed by same letter in the line, in the same unit, don't have significant difference to each other (Student's *t* Test,  $P > 0,05$ ).

The careful analysis of the data presented in Table 1 reveals that complementary studies should be made with the purpose of subsidizing the official organs, aiming the regulation of the process of spray-chilling. However, the importance of the continuous monitoring of the system must be emphasized, considering that each commercial beef slaughterhouse unit possesses its own characteres related to hygiene, crew, physical structure and equipments.

The American directive and also the Canadian establishes sampling plans, looking for the control of the process in the part of the Inspection Service. Similar plans could be elaborated and regulamented considering the peculiarities of the national industry.

With the main purpose of helping the Inspection Service in the control of the process, it is suggested the installation of an electronic seal in the controlled logical program, hindering possible alterations in the programming previously regulamented.

The average weight values of hot and chilled carcass from the control and treatment groups, as well as its differences or weight loss, are in Table 2. The evaporation weight loss verified in the control group of units A and B, 1.39 and 1.54%, respectively, is below the described values by PARDI et al. (1993), that mentioned weight loss above 2.0%. However, these values are inside the limits from 0.75 to 2.0%, pointed for KASTNER (1981) for beef carcasses chilled by the conventional air system.

It is observed in Table 2 that the average values of weight loss in the treatment group were lower to the ones verified in the control group, in both units. The difference observed in the weight loss among the units A and B, in the chilled carcasses, 0.39 and 0.96%, respectively, can be related to the fat that was covering the carcasses, besides the characteristics of relative air humidity and air velocity in the chilling room of each unit.

It is verified, in Table 2, the existence of highly significant difference ( $P < 0,001$ ) between the weight loss of the control and treatment group, in both units. This means that the process of spray-chilling beef carcasses can be considered advisable in economical terms. Making a projection for unit A, that had weight loss reduced from 1.39 to 0.39%, considering the slaughter of 600 animals/day, with average weight of 125kg/hot carcass side, the following situation would happen: loss of 2,085 kg due to the weight loss caused by the conventional air system, in opposition to only 585 kg lost, using the spray-chilling system. In other words, unit A would stop losing 1,500 kg/day.

The evaporation weight loss verified in the treatment group of unit B, 0.96%, is in agreement with information of ALLEN et al. (1987) and JONES et al. (1988), which informed that spray-chilling of

carcasses reduces the weight loss due to evaporation process in 0.5 to 1.5% in the first 24 hours. The average values of weight loss in the treatment group, in both units, also agree with GREER et al. (1990).

It is known that the conventional chilling process associate to spraying of cold water on the carcasses sides, presents advantages not only to the decrease of the weight loss, but also in the increase of velocity of temperature decrease of the carcasses sides, what contributes in some conditions to reduce growth and, consequently the bacterial count (GREER & DILTS, 1988).

The bacteriological results from the carcasses sides are in Table 3. It is verified that in unit A, the average values of the SPC and counts of psychrotrophic microorganisms, as well as the determination of the MPN of fecal coliforms, in swabs of the carcasses sides, did not differ to each other in a significant way ( $P > 0,05$ ). The values, that can be considered low, allow us to infer that the carcasses sides of the control and treatment groups of unit A shown satisfactory hygienic conditions. These results find back-up in GREER and JONES (1997) that, studying the bacteriological quality of sprayed beef carcasses, affirmed that it was not affected by the process from 4 to 16 hours.

In unit B, the average values of SPC and psychrotrophic counts, from swabs of carcasses sides, presented a significant difference to each other ( $P < 0,05$ ), showing a high decrease in the average values of the treatment group. The average values of determination of NMP of fecal coliforms, in both groups, did not show a significant difference to each other. The average values verified in unit B, for the three variables, can also be considered low, and show the good hygiene conditions that prevailed in the moment of the slaughter.

**TABLE 2.** Average values of weight and of its differences obtained for hot and chilled carcasses from the control and treatment groups, in the units A and B.

Unit	Control group				Treatment group			
	HC <sup>1</sup>	CC <sup>2</sup>	Difference		HC	CC	Difference	
			kg	%			kg	%
A - Average values	125.92	124.17	1.75 <sup>a</sup>	1.39	125.00	124.51	0.49 <sup>b</sup>	0.39
B - Average values	121.90	120.01	1.88 <sup>a</sup>	1.54	121.34	120.17	1.17 <sup>b</sup>	0.96

<sup>1</sup> HC: Hot Carcass

<sup>2</sup> CC: Chilled Carcass

<sup>a</sup> Values followed by different letters in the line, in the same unit, differ to each other significantly (Student's *t* Tests,  $P < 0,001$ ).

**TABLE 3.** Distribution of the average values of SPC, psychrotrophic counts and MPN of fecal coliforms, from swabs of carcass sides of units A and B.

Variables	Parameters	Unit A				Unit B			
		Control		Treatment		Control		Treatment	
		CQ <sup>1</sup>	CR <sup>2</sup>	CQ	CR	CQ	CR	CQ	CR
SPC (CFU/cm <sup>2</sup> )	Average	8.75	17.36 <sup>a</sup>	19.40	22.48 <sup>a</sup>	9.99	116.19 <sup>a</sup>	22.60	16.23 <sup>b</sup>
	Standard error	5.02	8.12	7.63	14.12	1.14	82.91	8.15	4.13
Psychrotrophic (CFU/cm <sup>2</sup> )	Average	7.79	9.23 <sup>a</sup>	2.15	5.09 <sup>a</sup>	77.34	21,460.67 <sup>a</sup>	3.63	21.99 <sup>b</sup>
	Standard error	4.09	4.72	0.68	1.46	75.69	21,428.12	1.28	15.71
NMP of fecal coliforms (germs/cm <sup>2</sup> )	Average	3.03	3.00 <sup>a</sup>	3.02	3.00 <sup>a</sup>	0.45	0.36 <sup>a</sup>	0.33	0.31 <sup>a</sup>
	Standard error	0.02	0.00	0.02	0.00	0.13	0.06	0.02	0.01

<sup>1</sup> HC: Hot Carcass<sup>2</sup> CC: Chilled Carcass<sup>a</sup> Average followed by same letter in the line, in the same unit, don't differ to each other significantly (Student's *t* Test, P>0,05).**TABLE 4.** Average values of free chlorine dosage, temperature determinations and bacteriological indicators of sprayed water quality, in units A and B.

Unit	Free chlorine (mg/L)	Temp. (°C)	SPC (CFU/mL) <sup>1</sup>	Total coliforms (germs/100 mL)	Fecal coliforms (germs/100 mL)
A- Average values	1.53	2.38	508.33	3.22	3.00
B- Average values	0.78	2.55	5.00	0.30	0.30

<sup>1</sup>CFU/mL: colony forming unit.

From the analysis of Table 3, it can be inferred that the conventional process of chilling associated to the spraying of the carcasses, and the good conditions of hygiene of the establishments before, during and after the slaughter contributed to the obtainance of counts and determinations of indicative microorganisms that can be considered low. It is noticed that the spraying process did not commit the bacteriological quality of the meat, providing the opposite, better quality than in the carcasses that were not sprayed. Such fact can be mainly related to the effects of the superficial wash, and to the water quality.

In Table 4, there are the average values of free chlorine dosage, temperature evaluations and bacteriological indicators of the sprayed water quality, in units A and B. It is noticed that the average results

of free chlorine dosage came inside the limits specified by the companies, in other words, 0.5 to 1.5 mg/L, although the national pattern is 1.0 mg/L (BRASIL, 1997). However, some samples provided inferior individual values to the minimum limit, and others to the maximum.

It is also noticed in the Table 4 that the average values of water temperature were above the value of +2°C, specified by the companies, indicating that the water temperature control should deserve more attention on the part of the commercial beef slaughterhouse.

The water bacteriological analysis used in the aspersion system of unit B revealed average values that can be considered low, and in agreement with the national patterns, in other words, 500CFU/mL to the SPC, and 23 germs/100 mL for MPN of total

and fecal coliforms (BRASIL, 1997). In unit A, the average value of the SPC came lightly above than what is recommended by the effective legislation.

It is suggested that the good bacterial quality of the water aspersion system should be considered extremely important, with the purpose of avoiding the contamination of the carcass sides and to help the reduction of bacterial population during the process of chilling.

## CONCLUSIONS

In the conditions in that the present assay was led, it is ended that:

- although the weight average of the carcass sides between the control and treatment groups in both units has not presented significant difference, it was observed that there are an remarkable differences in the average reduction of weight loss, indicating potentially economic advantages of the conventional process of chilling associated to spraying;

- the conventional process of chilling associated to spraying the beef carcass sides, did not change the physico-chemical quality and provided a reduction of counts and determinations of bacteriological indicators of meat. Therefore, it could constitute an analysis object on the part of the official organs of regulation and fiscalization, seeking for its definitive adoption.

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