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Stability of vacuum-packed meat from finishing steers fed different inclusion levels of brewer's spent grain

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ABSTRACT

Brewer's spent grain (BSG) as a partial substitute for corn silage (CS) was evaluated in finishing feedlot steers on the lipid, protein, color, and microbiological stability of vacuum-packed meat for 75 days under refrigerated storage. Twenty steers were distributed in four treatments in a completely randomized design with five replicates each: 50% concentrate + 50% CS; + 35% CS + 15% BSG; + 25% CS + 25% BSG; and 15% CS + 35% BSG for 90 days. After the animals were slaughtered and the carcasses cooled, the *Longissimus thoracis* muscle was collected for analyzes. The lipid and protein oxidation, color parameters and microbiological stability of the beef although not affected by the diets ($P > .05$) oscillated throughout the storage time ($P < .05$). BSG can be included in the finishing diets of beef cattle by up to 35% (dry basis) and as a forage source without adverse effects on beef shelf life.

1. Introduction

Beef shelf life is determined by oxidative processes influenced by temperature, exposure to oxygen, light, and microbial growth (Guerra-Rivas et al., 2016). Oxidation requires an oxidizing agent to have access to the substrate (lipid and protein). The most common oxidizing agent is oxygen from the air. Processes that exclude or reduce oxygen concentration, such as vacuum packaging, can prevent lipid oxidation. Vacuum packaging has been practiced as a means of extending the shelf life of meat (Guerra-Rivas et al., 2016; Wyrwisz et al., 2016).

Thus, the use of new technologies is essential to increase beef production and improve its quality to accord internal and external markets demands (Correia et al., 2016). The consumer preference for natural products and health benefits has intensified the search for methods to retard lipid oxidation in foods, including the use of natural antioxidants, which may be a suitable alternative in animal feedstuffs, thus avoiding any further manipulation of the meat (Castillo, Pereira, Abuelo, & Hernández, 2013; Guerra-Rivas et al., 2016).

In this context, meat quality can be affected by animal nutrition, and several agroindustrial by-products can be used as a source of forage or concentrates in diets (Guerra-Rivas et al., 2016; Oliveira et al., 2015). These alternative diets for cattle affect the sustainability of the systems and take into account global policies that have encouraged the use of by-products in order to compile two major objectives, which are decreasing environmental pollution by industries and increased use of low-cost animal feeding resources (Anandan, Zoltan, Khan, Ravi, & Blümmel, 2012; Santana Filho et al., 2016).

The brewing industry generates a low added-value- industrial by-product called brewer's spent grain (BSG) (Steiner, Procopio, & Becker, 2015). This by-product accounts for about 85% of the waste generated in the whole brewing process with an annual output of around 38.6 million tons worldwide (Mussatto, 2014). Typical compositions of BSG vary, although they always include high levels of fiber and protein, as well as appreciable levels of lipids and minerals (McCarthy, O'Callaghan, Piggott, Fitzgerald, & O'Brien, 2013; Mussatto, 2014).

BSG also contains a high amount of phenolic compounds with high antioxidant potential (Farcãs et al., 2015; Mussatto, 2014), among them, phenolic acids, particularly hydroxycinnamic acids, such as ferulic acid and p-coumaric acid (McCarthy et al., 2013; Stefanello et al., 2018). When BSG was compared with other ingredients (corn silage, rice bran, corn bran, and wheat bran) used in ruminant feeding, it had the highest concentration of polyphenols among the evaluated

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samples (Stefanello et al., 2018).

Although other studies have demonstrated that natural compounds can influence meat quality (Correia et al., 2016; Rivaroli et al., 2016) and prolong the shelf life of meat (Guerra-Rivas et al., 2016; Luciano et al., 2011) research on the effects of BSG on meat quality (used in animal feed) are still limited. Thus, this study aims to evaluate the potential use of BSG as a partial replacement for corn silage in the finishing diet of feedlot steers regarding stability of lipid, protein, color, and microbiological content of vacuum packed beef under refrigerated storage for 75 days.

2. Material and methods

2.1. Animals and diets

This study was carried out in accordance with the Ethics Committee of Federal University of Santa Maria, Brazil, under protocol 096/2014. The study employed twenty 16 month-old Angus steers with a mean live weight of 280 ± 20 kg from the same herd and born during the same calving season. The animals were randomly distributed in four homogeneous groups and housed in individual pens with a total area of 25 m^2. All steers had access to drinking water and feed ad libitum. The diets were offered as mixed ration.

The cattle were fed twice daily (8 am and 4 pm) with rice bran, wheat bran, and ground corn meal and mineral-vitamin supplement. As forage, the BSG was used instead of corn silage (CS) in the levels: zero, 15, 25 and 35% of the dry matter the diets. All BSG used in this study were obtained from pilsen malt from the same production lot. The diets were formulated using the Cornell (Cornell Net Carbohydrate and Protein System software - CNCPS, 2005) to provide a forage: concentrated ratio of 50:50 on the dry matter balanced to be similar in protein and energy (Table 1).

The steers were finished on their respective diets at 110 days, with 20 days for the animals to adapt to the management, experimental facilities, and diets.

2.2. Longisimus thoracis muscle sampling

The steers were slaughtered at a commercial slaughterhouse after a solid fasting period of 12 h, which is in compliance with the standards of the State Inspection Service legislation in Brazil (Brazil, 2000). The carcasses were then divided medially through the sternum and vertebral column, identified, and chilled below 4 °C for 24 h. The *Longissimus thoracis* (LT) was excised from the left side of the carcass between the 7th and 13th ribs for subsequent analysis.

The LT was sliced into steaks (2.5 cm thick), weighed, vacuum packed (Cryovac®, São Paulo, Brazil) in polyamide pouches of low permeability (thickness 90 µm, oxygen permeability 50 $cm^3/m^2/24$ h, CO_2 permeability 140 $cm^3/m^2/24$ h, water vapor permeability 6–8 g/$m^2/24$ h), and stored at 4 °C ± 2 °C protected from light for either 0, 15, 30, 45, 60, and 75 days (experimental period) for analyses in each period.

2.3. Lipid oxidation

Lipid oxidation of meat was assessed by monitoring the levels of thiobarbituric acid reactive substances (TBARS) using the method of Raharjo, Sofos, and Schmidt (1992).

2.4. Protein oxidation

Protein oxidation of meat was assessed by determining protein carbonyl (PC) content. The meat samples were homogenized (Model AP-56 – PHOENIX Luferco, São Paulo, Brazil) with phosphate buffered saline (1:4, w/v) for one minute. PC content was determined at 370 nm using 2,4-dinitrophenyl hydrazine (Levine et al., 1990) and normalized to protein content. Total protein was determined at 625 nm after reaction with Folin Ciocalteu and bovine serum albumin was used as standard (Lowry, Rosebrough, Farr, & Randall, 1951).

Table 1
Proximate composition, fatty acid profile and phenolic compounds of the ingredients used in experimental diets.

Ingredients	Concentrated			Forage	
	Rice bran	Ground corn grain	Wheat bran	Brewer's spent grain	Corn silage
Proximate composition (g/kg DM)					
DM	889.4	881.3	872.3	213.2	329.7
MM	101.7	15.0	46.7	39.7	100.5
CP	161.2	97.5	176.6	201.2	72.2
EE	199.1	39.8	42.1	81.6	32.1
NDFap	267.6	154.6	417.9	499.2	531.4
NFC	270.4	693.1	316.7	178.3	263.8
ADIN	1.6	0.9	0.9	3.6	3.8
NDIN	4.3	8.1	6.4	16.5	15.5
ADL	61.7	15.0	46.7	39.7	40.5
Fatty acid profile (g/kg methyl esters of fatty acid)					
14:0	2.5	2.4	2.9	3.9	5.9
16:0	169.5	130.4	154.2	209.6	143.2
16:1n-7	1.5	1.9	1.8	1.8	3.5
18:0	17.4	24.9	13.2	19.9	28.0
18:1n-9	430.2	308.6	202.1	136.2	283.1
18:2n-6	339.7	499.9	557.9	543.4	449.9
18:3n-3	16.1	12.0	44.1	52.9	57.4
20:0	8.7	5.4	1.5	3.3	5.0
20:1n9c11	5.6	2.7	8.0	9.6	2.6
22:0	3.3	1.7	1.2	3.2	2.5
24:0	5.3	2.9	1.6	2.6	4.0
SFA	206.7	170.6	179.5	248.8	198.3
MUFA	437.4	316.6	217.4	153.8	292.3
PUFA	355.9	512.7	603.2	598.4	510.4
Phenolic compounds (in kg DM)					
Total phenolics (g GAE)[a]	7.83	5.23	7.07	17.46	15.65
Phenolic acids (g)[b]					
p-coumaric acid	0.18	0.003	0.003	1.03	0.43
trans-ferulic acid	0.34	0.03	0.07	2.08	0.15
Sinapic acid	0.03	0.003	0.004	0.09	–
Total flavonoids (g QE)[c]	3.5	0.9	0.4	4.5	2.7

DM = dry matter; MM = mineral matter; CP = crude protein; EE = ether extract; NDFap = neutral detergent fiber corrected for ash and protein; NFC = non-fiber carbohydrates; ADIN = acid detergent insoluble nitrogen; NDIN = neutral detergent insoluble nitrogen; ADL = acid detergent lignin; C14:0 = myristic acid; C16:0 = palmitic acid; C16:1n7 = palmitolenic acid; C18:0 = stearic acid; C18:1n9 = oleic acid; C18:2n6 = linoleic acid; C18:3n3 = alpha linolenic acid; C20:0 = arachidic acid; C 20:1n9c11 = gondoic acid; C22:0 = behenic acid; C24:0 = lignoceric acid; SFA = saturated fatty acids; MUFA = mono-unsaturated fatty acids; PUFA = polyunsaturated fatty acids; GAE = Gallic acid equivalent; QE = quercetin equivalent.

[a] Obtained by colorimetric method with the Folin-Ciocalteu reagent according to Singleton, Orthofer, and Ramuela-Raventos (1999).

[b] Obtained by high performance liquid chromatography with methodology developed and validated by the authors in a previous study (Stefanello et al., 2018).

[c] Obtained by colorimetric method described by Bao, Cai, Sun, Wang, and Corke (2005).

2.5. pH measurements

The pH of the meat samples was determined by blending 10 g of meat with 100 ml of distilled water for 1.5 min in a homogenizer (Model AP-56 – PHOENIX Luferco, São Paulo, Brazil). The pH values were measured using an electrode attached to a digital pH meter (Model DM-22–DIGIMED; combined electrode DME-CV1, São Paulo, Brazil).