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Diferentes fontes de selênio adicionado a dieta de grão de milho inteiro na fase de terminação de novilhos Angus

Different sources of selenium added to whole corn grain diet in the finishing phase of Angus steers

Se agregaron diferentes fuentes de selenio a la dieta integral de granos de maíz en la etapa final de los novillos Angus

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Resumo

O selênio é um mineral essencial sendo cofator de enzimas antioxidantes, dentre as fontes disponíveis no mercado o selenito de sódio (fonte inorgânica) é a mais estuda e utilizada, contudo fontes orgânicas têm sido descritas como mais eficientes. Com base nisso o objetivo deste estudo foi avaliar se as diferentes fontes inorgânica (selenito de sódio) e orgânica (selenometionina) na dieta de grão de milho inteiro para terminação de novilhos Angus apresentam efeitos sobre desempenho e qualidade de carcaça e carne. Para isso, foram selecionados 22 animais, divididos em: grupo selenito de sódio (SS=11) e grupo selenometionina (SM=11). O confinamento foi de 82 dias, sendo realizadas 4 pesagens. Foi mensurado o peso de carcaça, temperatura e pH ao abate e 24 horas, rendimento de carcaça, perdas por resfriamento, pH, cor, e espessura da gordura subcutânea. Amostras do músculo *Longissimus thoracis* foram retiradas entre 12º e 13º costelas da meia carcaça esquerda para mensuração de largura e profundidade do músculo, área de olho de lombo, coloração e pH da carne em 24 horas e 48 horas, além de demais análises laboratoriais como: maciez, perda por cocção, TBARS e concentração de selênio. Não houve diferença entre os grupos para os parâmetros de desempenho e qualidade de carcaça e carne, bem como para concentração de selênio e tempo de congelamento. Portanto, ambas as fontes de selênio podem ser usadas nas dietas de grão de milho inteiro para terminação de novilhos Angus e apresentam os mesmos efeitos sobre desempenho, qualidade de carcaça e carne.

Palavras-chave: Confinamento; Qualidade de carne; Selenometionina.

Abstract

Selenium is an essential cofactor for antioxidant enzymes. Among the sources available on the market, sodium selenite (inorganic source) is the most used and studied; nevertheless, organic sources have been described as being more efficient. Against this background, the

objective of the present study was to determine whether various selenium sources, both inorganic (sodium selenite) and organic (selenomethionine), in the whole grain feed for finishing Angus steers would affect performance as well as carcass and meat quality. For this purpose, 22 animals were selected and were divided as follows: sodium selenite group (SS = 11) and selenomethionine group (SM = 11). The feedlot period was 82 days, with 15 days of adaptation and a total of four weighings. We measured carcass weight, slaughter temperature, and pH, after 24 h carcass yield, cooling loss, pH, color, and subcutaneous fat thickness. *Longissimus thoracis* muscle samples were taken between 12th and 13th ribs of the left half carcass to measure muscle width and depth, rib-eye area, meat color and pH at 24 hours and 48 hours, in addition to other laboratory analyses, including tenderness, cooking losses, thiobarbituric acid reactive substances, and selenium concentration analysis. There were no differences between groups with respect to performance or carcass and meat quality, as well selenium concentration and freezing time. These findings suggest that both selenium sources can be used in whole grain feed for finishing Angus steers and that they have the same effects on performance and carcass and meat quality.
Keywords: Feedlot; Meat quality; Selenomethionine.

Resumen

El selenio es un mineral esencial y es un cofactor de las enzimas antioxidantes. Entre las fuentes disponibles en el mercado, el selenito de sodio (fuente inorgánica) es el más estudiado y utilizado, sin embargo, las fuentes orgánicas se han descrito como más eficientes. En base a esto, el objetivo de este estudio fue evaluar si las diferentes fuentes inorgánicas (selenito de sodio) y orgánicas (selenometionina) en la dieta integral de granos de maíz para engordar novillos Angus tienen efectos sobre el rendimiento productivo, de la calidad de canal y de la carne. Para esto, se seleccionaron 22 animales, divididos en: grupo de selenito de sodio (SS = 11) y grupo de selenometionina (SM = 11). El confinamiento fue de 82 días, con 4 pesajes. Se mensuraron el peso, la temperatura y el pH de la canal al sacrificio y 24 horas, el rendimiento de la canal, las pérdidas por enfriamiento, el pH, el color y la espesura de la grasa subcutánea. Se tomaron muestras del músculo Longissimus thoracis entre las costillas 12º y 13º de la mitad de la canal izquierda para medir el ancho y la profundidad del músculo, el área del ojo bife, el color y el pH de la carne en 24 horas y 48 horas, además de otras análisis de laboratorio como: sensibilidad, pérdida de cocción, TBARS y concentración de selenio. No hubo diferencias entre los grupos para el rendimiento productivo y los parámetros de calidad de la canal y de la carne, así como para la concentración de selenio y el tiempo de congelación. Por lo tanto, ambas fuentes de selenio se pueden usar en dietas integrales de maíz para engordar novillos Angus y tienen los mismos efectos en el rendimiento productivo, la calidad de la canal y la carne.

Palabras clave: Calidad de la carne; Confinamiento; Seleniometionina.

1. Introduction

Among cattle finishing feeds, whole grain or high grain corn systems stand out. Such systems consist of feed composed exclusively of grains, without any addition of roughage. These feeds are composed of whole corn grains and pellets, the second of which meets the requirements of proteins, vitamins, and minerals (Owens et al., 1997). Vitamins and minerals are included in small amounts; however, they perform functions fundamental to the organism, and their absence can cause problems and poor performance (Zanetti et al., 2000). The micro-mineral selenium (Se) participates in growth, reproduction, disease prevention and is a cofactor of the enzyme glutathione peroxidase, an antioxidant enzyme (McDowell, 1999; Lima and Domingues, 2007; Junior et al., 2011).

According to Spears (1996), supplementation with selenium improves the reduction of oxidation in meat, which directly reflects the quality as well as factors related to lipid oxidation. These factors are responsible for the characteristic rancid taste and odor (called “off flavors” and “off odors”) caused by the oxidation of the lipids present in the meat (Junior et al., 2013). On the market, there are inorganic and organic sources of this mineral, the second of which having more availability, higher biological value, and ability to be stored in tissues (Li et al., 2018). Wei et al. (2019) noted that selenium yeast is the most used organic source in food supplementation. However, Mendi et al. (2015) pointed out that minerals complexed with amino acids, for example methionine and cysteine, are prominently represented in organic sources because of their better effects on meat quality, a fact explained by the greater availability.

Among the most recent studies with organic sources, Silva et al. (2019) evaluated the supplementation at various doses (0.3, 0.9, and 2.7 mg Se/kg DM) and different sources (organic and inorganic) for Nellore cattle under traditional feedlot. However, the effects of selenium supplementation complexed with the amino acid methionine on the parameters of performance and quality of carcass and meat of Angus steers in a whole corn grain diet are not known. Therefore, the objective of this study was to determine whether the different sources (sodium selenite and selenomethionine) would influence performance, carcass quality, and meat of Angus steers finished on whole corn grain feed.

2. Materials and Methods

This study had an exploratory and quantitative nature (Pereira et al., 2018). To achieve our objectives, we used a completely randomized design, as detailed below.

For the experiment, 22 male castrated Aberdeen Angus animals were selected, with a mean age of 15 months (± 2 months) and initial weight of 375 kg (± 26 kg). The groups were divided into two treatments, one with sodium selenite – SS (n = 11) and the other with selenomethionine – SM (n = 11). The doses followed recommendations proposed by the NRC (2001). The animals were placed in collective pens protected from sun and rain, fitted with covered feeders. The feeding trough was 40 cm (± 2 cm) for both groups. The experiment was carried out in the municipality of Otacílio Costa-SC, (28°39′30″S and 56°31′48″W), with Cfb climate, annual temperature of 16.3 °C on average and average annual rainfall of 1519 mm.

The total period of the experiment was 82 days, with 15 days of adaptation constituting the first 5 days, with provision of 3.75 kg of the whole grain feed (1% of BW), composed of 85% corn and 15% protein concentrate-mineral-vitamin-additive (Turbo Grão Engorda-Nutramix®) + 3 kg of ryegrass hay (*Lolium multiflorum*). From the 6th to the 10th day, we offered 5.63 kg of the whole grain diet + 2 kg of ryegrass hay. From the 11th to the 15th day, we offered 6.75 kg of the diet + 1 kg of hay; and from the 16th day until the time of slaughter, the animals received only the whole grain mixture (85% corn + 15% Turbo Grão Engorda®) at will in covered feeders, according to Table 1.

Table 1 - Composition of the feedlot diet and calculated composition.

Ingredient	Confinement diet
Corn	85%
Protein-mineral-vitamin-additive pellet	15%
Total	100%
Calculated total mixed diet	
Dry matter	88.25%
Crude protein	13.30%
Crude fiber	3.02%
Ethereal extract	3.06%
Acid detergent fiber	8.36%
Neutral detergent fiber	26.88%
Total digestible nutrients	73.42%
Ash	4.27%
Moisture	11.75%
Selenium	0.24 mg

Source: Authors.

Four individual weighing were carried out during the experiment; however, only at the first and the last animals were the animals fasting. At the end of confinement, the animals were slaughtered using mechanical stunning according to current legislation, in a commercial slaughterhouse located in the city of Rio do Sul (distance 35 km). Immediately after slaughter, measurements of hot carcass weight (forequarter and hindquarter weight), pH and temperature were performed using a Hanna Instruments portable device (model HI99163). The triplicate measurements for parameters of luminosity (L), intensity of green to red (A) and intensity of blue to yellow (B), were performed using a colorimeter (Minolta Chroma Meter, model CR 400) according to the CIELAB system performed between the 12^{th} and 13^{th} ribs and in the longissimus thoracis muscle at 0, 24, and 48 hours.

After 24 hours in a refrigerator, the carcasses were weighed again and the difference between weighing gave losses due to cooling. We also measured pH, temperature, and subcutaneous fat between the 12^{th} and 13^{th} ribs of the left half-carcass. At the same measurement site, a section was performed on the longissimus thoracis muscle. From this section, samples (steaks) approximately one inch thick were taken. Subsequently, the rib eye area (REA/cm²) was determined. Using parchment paper, the longissimus thoracis muscle was manually drawn for further analysis using ImageJ® software. In the longissimus thoracis muscle, the width and depth were measured manually using a ruler, and the subcutaneous fat thickness (SFT) using a digital caliper.

The samples (steaks) were individually vacuum-packed in the slaughterhouse and refrigerated between 0 and 5 ºC for further analysis. In the Animal Products Technology Laboratory at UDESC/Oeste, the refrigerated samples were exposed to atmospheric air for 30 minutes, and subsequently pH, temperature, and meat color measurements were made. For cooking loss, expressed by the difference between weighing before and after cooking, the samples were weighed and a thermometer was introduced in the center of the steak, placed on the grill to cook until the internal temperature reached 71 ºC. Eight sub-samples were taken from each steak, cylindrical in shape and 1.27 cm in diameter, in the direction of the muscle fibers. Using a Texture Analyzer texturometer (model TA-XT2I) we measured the tenderness as shear force, expressed as Kg/cm² (shear force).

For the analysis of thiobarbituric acid reactive substances (TBARS), meat samples were frozen for 30, 60, and 90 days. For each period, they were then lyophilized in a Terroni freeze-drying device (model LS). After lyophilization, the samples were stored again in a freezer until analysis, as described by Jentzsch et al. (1996).

For the analysis of selenium in meat, the preparation followed the methodology described by Instituto Adolfo Lutz (2008). The technique consists of the elimination of organic materials from the sample. To do this, the lyophilized sample was dried in an oven (105 ºC) for 24 hours. Subsequently, using a Bunsen burner with an asbestos screen, the samples were burned until all smoke was completely released. The samples were then burned in a muffle furnace (400–450 ºC). At 4-hour intervals, the samples were removed and submerged in nitric acid, dried again in a Bunsen burner and returned to the muffle. This procedure was repeated until obtaining light ashes, free from charcoal or organic matter. Then, the residual matter present in the crucible was washed with deionized water to remove trace minerals and analyzed in atomic absorption spectrophotometry in a graphite furnace with contrAA® 700 equipment (Analytik Jena). Selenium content was expressed as mg of Se/kg of meat.

The data were subjected to analysis of variance with an entirely randomized design and the results were compared with one another using the F (Fischer) test at 5% significance.

3. Results and Discussion

The results regarding the analysis of live weight throughout the experiment are shown in Table 2. The results of live weight did not differ (P > 0.05) among the sources of supplemented selenium. Our findings corroborate those of Silva et al. (2019), who supplemented two sources (sodium selenite and yeast selenite) in four doses in finishing Nellore cattle in traditional feedlots (corn silage and concentrate). Gozzi et al. (2011) supplemented 0.3 mg of Se/kg of DM as the sources of sodium selenite and selenium yeast; they also did not find a significant result for weight gain.

Table 2 – Weight (mean ± standard error) in different periods for the treatments Selenomethionine (SM) and Sodium Selenite (SS).

Parameter	SM	SS	CV	P-value
Weighing 1 - day 0 (kg)	371.55 (25.00)	377.18 (27.49)	7.02	0.6204
Weighing 2 (kg)	402.00 (40.87)	406.91 (31.95)	9.07	0.7569
Weighing 3 (kg)	430.91 (36.06)	442.36 (34.72)	8.11	0.4568
Weighing 4 24-h before slaughter (kg)	437.00 (36.50)	453.09 (29.52)	7.46	0.2691

*****CV = coefficient of variation.
Source: Authors.

Davy et al. (2016) found that selenium may not change animal weight gain, in an experiment carried out with different sources and supplementation modes (injectable or in the feed). The authors found no significant difference for weight gain. They surmise that a possible difference in weight would be indirectly associated with improvement in immunity and health.

In the present study, there were no differences between groups in terms of muscle temperature (P = 0.6306) and meat (24-h) at slaughter (P = 0.1589). These values (Table 3) are consistent with those of literature, suggesting that pre- and post-slaughter handling did not interfere with meat quality (Bianchini et al., 2007; Gomide et al., 2006). The pH of the muscle at slaughter (P = 0.1874), at 24 hours (P = 0.9753), and at 48 hours (P = 0.4135), did not differ between treatments (Table 4). The values found were close to those previously reported in the literature (Bruce, 2004; Gozzi et al., 2011). For parameters L, A, and B of fat at the time of slaughter and at 24 hours in muscle (0 h) and meat (24-h), no differences were found between the groups (Table 4).

Table 3 – Carcass and meat temperature and pH (mean ± standard error) at different periods for the treatments selenomethionine (SM) and sodium selenite (SS), coefficient of variation (CV) and P-value.

Parameter	SM	SS	CV	P-value
Slaughter temperature (ºC)	35.72 (0.90)	35.49 (1.25)	3.06	0.6306
24-h temperature (ºC)	12.28 (1.57)	11.48 (0.90)	10.79	0.1589
Slaughter muscle pH	6.87 (0.24)	6.74 (0.17)	3.05	0.1874
24-h meat pH	5.83 (0.33)	5.83 (0.20)	4.66	0.9753
48-h meat pH	5.40 (0.06)	5.42 (0.07)	1.23	0.4135

*****CV = coefficient of variation.
Source: Authors.

Gozzi et al. (2011) kept meat samples from animals supplemented with sodium selenite and selenium yeast in packages without air for 6 and 11 days; the meat from animals supplemented with selenium yeast had a higher luminance index in these periods. This is an important parameter from the standpoint of the consumer at the time of purchase (Kropf, 1980; Wulf et al., 1997). Hot carcass weight, cold carcass weight, hindquarter weight, forequarter weight, cooling loss, cooking yield, carcass yield, shear force, rib eye area, subcutaneous fat, depth, and width of steak did not differ between treatments (Table 5).

The rib eye area results were similar to those found by Del Claro (2013) and Lawler et al. (2004), who observed no effect on this parameter when supplementing different sources of selenium. The shear force found in the experiment was below that reported by Vaz et al. (2007) in an experiment with Angus on pasture (9.23 Kgf/cm²). However, Arboitte et al. (2011) found an average value of 2.72 Kgf/cm², for super young Angus given feed based on sorghum silage and concentrate. Costa et al. (2002) and Latimori et al. (2008) found values of 4.1 and 3.2 Kgf/cm², respectively, in Angus meat. According to Knapp et al. (1989), meats with values less than 4.50 Kgf/cm² are generally better accepted and are classified as tender by the consumer market. Restle et al. (1999) stated that the biggest beneficiary of the slaughter of young animals, without a doubt, is the consumer. The results for shear force, cooking losses and dripping corroborate those of Silva et al. (2019) who provided sodium selenite and selenium yeast in dosages of 0.9 and 2.7 mg Se/Kg; however, they did not observe significant results.

Table 4 – Parameters L, A, and B (mean ± standard error) for selenomethionine (SM) and sodium selenite (SS) for subcutaneous fat at slaughter (0 h), 24 hours and muscle color (0 h) and meat (24-h) coefficient of variation (CV) and P-value.

Parameter	SM	SS	CV	P-value
Slaughter fat (0 h)				
L*	64.01 (1.25)	63.71 (1.63)	2.27	0.6309
A*	2.87 (0.78)	2.44 (1.34)	41.39	0.3628
B*	14.07 (1.15)	14.31 (1.79)	10.59	0.7108
Fat (24-h)				
L*	68.46 (2.39)	67.35 (1.74)	3.09	0.2283
A*	4.16 (1.67)	4.88 (1.48)	34.89	0.2978
B*	16.34 (0.84)	16.37 (1.49)	7.39	0.9500
Muscle (0 h)				
L*	37.65 (1.37)	37.23 (1.44)	3.76	0.4916
A*	17.30 (6.04)	16.07 (1.39)	26.01	0.9150
B*	10.30 (0.91)	10.49 (0.98)	9.10	0.6334
Meat (24-h)				
L*	39.07 (1.87)	39.57 (2.30)	5.33	0.5800
A*	16.09 (1.38)	16.07 (1.23)	8.15	0.9718
B*	10.03 (1.12)	10.82 (1.03)	10.31	0.1024

***CV** = coefficient of variation.
Source: Authors.

In the present study, no significant difference was observed between the sources of selenium concentration in the longissimus thoracis muscle (P = 0.2693, Table 5), a result different from that of Souza (2008), who reported significant differences between the sources of selenium (organic and inorganic) in bovine carcasses supplemented with 0.21 mg/Se kg in dry matter. In their study, the mineral averages were 0.148 mg/kg for organic source and 0.122 mg/kg for inorganic source; whereas in our study, they were 0.053 and 0.051 mg of Se/kg of meat for inorganic and organic sources, respectively.

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Table 5 - Carcass and meat characteristics (mean ± standard error) for selenomethionine (SM) and sodium selenite (SS), coefficient of variation (CV) and P-value.

Parameter	SM	SS	CV	P-value
Hot carcass weight (kg)	231.96 (24.11)	239.15 (17.13)	8.88	0.4295
Cold carcass weight (kg)	227.64 (22.94)	233.76 (17.14)	8.78	0.4867
Hindquarter weight (kg)	71.82 (6.90)	73.95 (5.11)	8.34	0.4200
Forequarter weight (kg)	41.99 (4.76)	42.87 (3.74)	10.09	0.6358
Cooling loss (%)	1.83 (0.61)	2.26 (0.56)	28.53	0.0982
Cooking loss (%)	10.18 (3.38)	11.85 (3.06)	29.26	0.2395
Carcass yield (%)	53.01 (1.65)	52.78 (1.83)	3.31	0.7675
Shear force (Kgf/cm²)	4.85 (0.77)	5.06 (0.68)	14.73	0.5117
Rib eye area (cm²)	58.53 (6.60)	60.80 (4.64)	9.57	0.3627
Steak depth (cm)	5.34 (0.47)	5.54 (0.47)	8.71	0.3518
Steak width (cm)	12.06 (0.99)	11.79 (0.55)	6.74	0.4527
Subcutaneous fat (mm)	6.47 (3.13)	5.89 (2.18)	71.54	0.9512
**TBARS 30-day (mg MDA/kg)	2.71 (1.02)	2.10 (1.08)	43.81	0.1849
**TBARS 60-day (mg MDA/kg)	2.25 (0.73)	2.50 (0.84)	32.24	0.4593
**TBARS 90-day (mg MDA/kg)	2.93 (0.89)	2.63 (0.69)	28.75	0.3971
Average TBARS (mg MDA/kg)	2.63 (0.50)	2.41 (0.61)	22.33	0.3717
Selenium (mg/kg)	0.051 (0.001)	0.053 (0.004)	6.03	0.2693

*CV = coefficient of variation.
** TBARS in meat, expressed on different freezing days.
Source: Authors.

Souza (2008) supplemented 0.3 mg Se/kg of DM in organic and inorganic sources for male, castrated Nellore cattle, and found no significant difference for carcass yield, rib eye area, subcutaneous fat thickness, marbling score, cooking losses, or tenderness. However, they found a higher concentration of the mineral in the muscle tissue of animals that received the organic source. Silva et al. (2019) supplemented two sources of selenium (sodium selenite and yeast selenite) and three doses (0.3; 0.9 and 2.7 mg Se/kg DM) for Nellore cattle. They found that the animals that received the highest dose of organic Se had a concentration of 0.3727 mg Se/kg in the latissimus dorsi muscle. Gozzi et al. (2011) reported that concentration of selenium in the longissimus thoracis muscle was higher in animals that received selenium yeast compared to those that were fed sodium selenite. Rossi et al. (2017)

supplemented 0.32 mg Se/kg DM from two sources (yeast and sodium selenite), and observed that the animals that received the organic source had a higher concentration of serum selenium, less occurrence of respiratory diseases, better antioxidant status, increased antibody levels, and overall better performance.

When comparing organic (selenomethionine) and inorganic (sodium selenite) sources in grouper (*Epinephelus malabaricus*) at dosages 0.3, 0.7, 1.0, and 1.5 mg/Se/kg/DM of the diet, investigators observed that, for 1.0 and 1.5 mg/kg, the concentration of Se in the meat was higher in fish fed with organic selenium, whereas in those given 1.0 mg/Kg, there were 0.36 mg and 0.15 mg of Se/kg of meat for organic and inorganic sources, respectively (Lin, 2014). Bakhshalinejad et al. (2019) tested different doses (0.1 and 0.3 mg) and sources (sodium selenite, selenomethionine, yeast selenium, and nano-selenium), and observed that the average between the two doses for nano-selenium source was equal to that of yeast selenium and higher than those of selenomethionine and sodium selenite. Results for sodium selenite, selenomethionine, and yeast selenium were the same.

In the present study, there was no difference for TBARS in meat (Table 5) for the 30, 60, and 90 days of freezing. For Silva et al. (2019) with storage and exposure similar to those of the market at 0, 2, 4, and 6 days without freezing, selenium supplementation reduced lipid and protein oxidation. The authors pointed out that oxidation was 15.51% higher in the inorganic source compared to the organic source of the mineral. The effects of meat oxidation have also been studied recently by Li et al. (2018) who supplemented with selenomethionine and sodium selenite. They observed a decrease in the concentration of TBARS in the meat, losses due to cooking and shear strength for birds that received the organic source of the mineral. Following the freezing methodology for various periods of time, no similar studies were found that used some source of selenium. Organic selenium supplementation decreased TBARS in pork (Calvo et al., 2017), poultry (Almeida et al., 2012; Li et al., 2018), and sheep (Vignola et al., 2009). According to the authors, the organic mineral source, having better availability, activates the enzyme glutathione peroxidase and the higher concentration of the enzyme inhibits the oxidation of lipids. As mentioned, some studies found significant results for performance characteristics, and others found them for meat quality and conservation; nevertheless, most studies cite selenium-yeast as an organic source, which may raise doubts as to the action and benefit of the complexed source (selenomethionine). For the purposes of the present study, there were no differences between the sources.

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4. Final Considerations

Selenium has several positive effects on mammalian health, and it is essential in the composition of animal feeds. Sodium selenite is the primary form of selenium in animal feeds, although many studies show that organic forms such as selenomethionine might be absorbed better. Our hypothesis was that the organic source of selenium would be able to enhance performance and improve meat quality. However, after analyzing the data, we concluded that two different selenium sources made no difference in terms of performance and meat quality in Angus steers given whole corn grain feed in the finishing phase.

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Ethics and biosafety committee

The protocol approved under the institutional CEUA of UDESC: number 9482080518.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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