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Use of flaxseed (*Linum usitatissimum*) in the diet of dairy cows: Review

Marcio Gregório Rojas dos Santos^{1*}, Pedro Gustavo Loesia Lima¹, Rodrigo Carvalho Ferreira², Marcus Vinícius Moraes de Oliveira³

¹PhD Student Animal Science in States University of Maringá, Maringá-PR Brazil. *Author for correspondence. E-mail: pg52944@uem.br

¹PhD Student Animal Science in States University of Maringá, Maringá-PR Brazil. E-mail: pedroloesia@gmail.com

²Student Animal Science in States University of Mato Grosso do Sul, Aquidauana-MS Brazil. E-mail: rodrigocarvalho@gmail.com

³Doctor Animal Science in States University of Mato Grosso do Sul, Department of Animal Science. Aquidauana-MS Brazil. E-mail: marcusvmo@yahoo.com.br

ABSTRACT. The use of lipids in the diet of dairy cows is widely spread in animal production, since these have great ability to assist in recovery from stress caused by postpartum, where animals are in poor body condition, from low consumption of dry matter in the state of negative energy balance. Ruminants receive the lipids, mainly in esterified form (mono-and diglycerides) in the fodder and focused in the form of triglycerides. After the intake of lipids, these chemical changes occur in the ruminal environment, changing the composition and profile of fatty acids. Flaxseed is very rich in linoleic acid (C18:2), which is an important fatty acid secreted by the mammary gland and in humans is associated with the fight against free radicals. Such characteristics are studied by agricultural sciences professionals to optimize the diet of dairy cows, with the aim of increasing conjugated linoleic acid content (CLA) in milk. The objective of this review was to facilitate the understanding on the issues of metabolism, milk composition and performance of dairy cows placed in front of the supplementation with flaxseed.

Keywords: supplementation, alternative food, metabolism

Utilização de semente de linhaça (*Linum usitatissimum*) na dieta de vacas leiteiras: Revisão

RESUMO. A utilização de lipídios na dieta de vacas leiteiras é amplamente difundida na produção animal, visto que estes possuem grande capacidade de auxiliar na recuperação do estresse durante o pós-parto, onde os animais estão em condição corporal deficiente, advindo do baixo consumo de matéria seca no estado de Balanço Energético Negativo. Os ruminantes recebem os lipídios, principalmente na forma esterificada (mono e diglicerídeos) nas forragens, e nos concentrados na forma de triglicerídeos. Após a ingestão dos lipídios, ocorrem modificações químicas destes no ambiente ruminal, alterando a composição e o perfil dos ácidos graxos. A semente de linhaça é rica em ácido linoleico (C18:2), sendo este um importante ácido graxo secretado pela glândula mamária e em humanos está associado ao combate aos radicais livres. Tais características são estudadas por profissionais de ciências agrárias para otimizar a dieta de vacas leiteiras, com o intuito de aumentar o teor de ácidos linoleicos conjugados (CLA) no leite. O objetivo da presente revisão foi facilitar o entendimento quanto às questões de metabolismo, composição do leite e desempenho de vacas leiteiras colocadas frente à suplementação com semente de linhaça.

Palavras chave: suplementação, alternativa alimentar, metabolismo

Uso de la semilla de linaza (*Linum usitatissimum*) en la dieta de vacas lecheras: Revisión

RESUMEN. La utilización de lípidos en la dieta de vacas lecheras es ampliamente difundida en la producción animal, ya que éstos poseen gran capacidad de auxiliar en la recuperación del estrés durante o posparto, donde los animales están en condición corporal deficiente, proveniente del bajo consumo de materia seca en el estado de Balance Energético Negativo. Los rumiantes reciben los lípidos, principalmente en la forma esterificada (mono y diglicéridos) en los forrajes, y en los concentrados en forma de triglicéridos. Después de la ingestión de los lípidos, ocurren modificaciones químicas de éstos en el ambiente ruminal, alterando la composición y el perfil de los ácidos grasos. La semilla de linaza es rica en ácido linoleico (C18: 2), siendo este un importante ácido graso secretado por la glándula mamaria y en humanos está asociado al combate de radicales libres. Tales características son estudiadas por profesionales de ciencias agrarias para optimizar la dieta de vacas lecheras, con el propósito de aumentar el contenido de ácidos linoleicos conjugados (CLA) en la leche. El objetivo de la presente revisión fue facilitar el entendimiento en cuanto a las cuestiones de metabolismo, composición de la leche y desempeño de vacas lecheras colocadas frente a la suplementación con semilla de linaza.

Palabras clave: suplementación, alternativa alimenticia, metabolismo

Introduction

The addition of lipids in the diet of lactating cows features advantage, mainly by providing increased energy level of the diet ingested and, consequently, improve the production of milk. This greater energy density is of fundamental importance, especially in the early stages of lactation, where the cow has reduced consumption by your postpartum with reduction of up to 30% on dry matter intake ([NRC, 1989](#)).

The lipids are an alternative to change the composition and physico-chemical characteristics of milk, especially the percentage of protein ([Sniffen et al., 1992](#)). In addition, when provided in free form, form a physical barrier about food particles, making colonization of ruminal microbiota, with consequent changes in microbial products.

Second [Chalupa et al. \(1986\)](#) oil seeds have high content of unsaturated fatty acids. So, when provided in the form of oils, present certain toxicity to bacteria cellulolytic, reducing the ratio: acetate propionate with acetic acid suppression, the main precursor of fat in milk.

The ruminant diet consists of approximately 3% of lipids, in order to reduce the damaging effects of fatty acids to microorganisms, and consequently on the ruminal fermentation ([Byers & Schelling, 1989](#)). However, when the oil seeds are provided in full form, can reduce the negative effects that affect fermentation, as a result of the

lower contact of the fatty acids with ruminal microorganisms.

The flaxseed according to your composition, features of 24,7% crude protein and 35,5% fat ([Petit, 2003](#)) making it an excellent source of protein and energy for cows in lactation.

For ruminants reared in tropical regions, the use of oilseeds is still interesting to reduce the caloric increase with the increase of the energy density of the diet, aiding in the process of acclimatization ([Paula et al., 2013](#)).

Lipids in the diet of lactating cows

The use of lipids in the diet of ruminants in general aims to increase the energy density of the diet ([Schingoethe & Casper, 1991](#)). The supplements fat in the form of oils, with a limit of up to 6% of the dry matter of the diet, promoting little influence on the consumption of animals. However, it is often observed decrease in digestibility of structural carbohydrates and change in the ratio of short-chain fatty acids in the rumen (acetic, propionic and butyric acid), and may the latter vary, mainly due to the way that supplemental lipid is performed, i.e. in the form free or protected ([Schingoethe & Casper, 1991](#)).

The addition of lipids in the diet of ruminants, in the form of oil seeds integrals (naturally protected), has less negative effect on consumption and digestibility, due to slow release of seed oil, than if a similar amount is given in the unimpeded form ([Kennelly, 1996](#)). The

deleterious effects of the oils are caused by various reasons, such as the formation of a physical barrier that prevents micro-organisms to degrade the fibrous components of diet; and the susceptibility of gram-positive bacteria, with consequent modification of ruminal microbiota and fermentation process.

[Jenkins \(1993\)](#) supports also the mitigation of negative effects of lipids through the use of oil seeds whole, considering that these do not interfere in the process of biohydrogenation of the fatty acids in the diet. According to [Jenkins & Jenny \(1989\)](#) the post the hydrolysis of unsaturated fatty acids, fatty acid saturation happens through hydrogenation of the double bonds.

Lipid metabolism in ruminants

Ruminants receive the lipids in the diet, mainly in esterified form in mono and diglycerides, found in forage, and food concentrates in the form of triglycerides ([Van Soest, 1994](#)). Grasses with forage potential have a mean of 3% lipids in the dry matter ([Kozlosk, 2011](#)) well below that of oilseeds.

Chemical modifications in lipids occur in the ruminal environment, changing the composition and profile of fatty acids ([Franco & Davy, 2007](#)). In the rumen, occur two important processes for lipid degradation, lipolysis and biohydrogenation, both conducted by ruminal microbiota ([Van Soest, 1994](#)).

Lipolysis is defined as the breaking of links esters found in the lipids of foods the diet followed by biohydrogenation of unsaturated fatty acids (AGI), which decreases the number of double bonds of AGI fat sources ([Jenkins, 1993](#)).

The short-chain fatty acids, also called volatile fatty acids are produced in large quantities by ruminants and possessing chains of one to seven carbon atoms, the main ones being the, the propionic and butyric acid ([Bergman, 1990](#)).

The biohydrogenation is in the process of breaking of the double bonds by microbial enzymes (lipolysis) and consequent addition of hydrogen ([Sullivan et al., 2004](#)); it has the function of protecting the ruminal microorganisms of effects deleterious of fatty acids, unsaturated. In this way the inclusion of high amounts of lipids in diet (above 7,0% of dry matter) may affect the

fiber digestibility and performance of the animal ([Jenkins, 1993](#)).

After the break, the polyunsaturated fatty acids become available to microorganisms to biohydrogenation occurs, starting by isomerization of *cis*-12 of linoleic and linolenic acids for *trans*-11, which when resulting from linolenic acid, form AG *cis*-9, *trans*-11, or conjugated linoleic acid (CLA). Then, the double bond is *cis*-9 hydrogenated, producing C18:1 *trans*-11 and C18:2 *trans*-11, *cis*-15 for linoleic and linolenic acids, respectively. The C18:2 *trans*-11, *cis*-15 undergoes a hydrogenation in the *cis*-15, producing also C18:1 *trans*-11, which is also in C 18:1 hydrogenated *trans*-11, stearic acid, C18:0 ([Pennington & Davis, 1975](#)). It should be noted that the biohydrogenation process is not complete, and there is a high proportion of conjugated linoleic acid, as well as of its isomers.

Approximately 10% polyunsaturated fatty acids escape from biohydrogenation rumen, duodenum, basically, small amounts of polyunsaturated fatty acids, saturated fatty acids, and microbial lipids. This small amount seems sufficient to meet the requirements of ruminants, because they do not seem to present shortcomings of these fatty acids ([Cavalieri et al., 2005](#)). However, it is remarkable the importance of unsaturated fatty acids in cell membranes, being the same responsible for keeping your structure, flow and function.

According to [Oliveira et al. \(2004\)](#) in order to reduce biohydrogenation and increase the amount of polyunsaturated fatty acids that reach the small intestine is necessary provide diets high in these acids, but also, that to be able to high Cap air the rumen pH.

The main bacteria responsible for biohydrogenation are the cellulolytic, because they are most affected by fat supplementation and by decrease of pH ([Palmquist & Jenkins, 1980](#)). When the fiber is replaced by rapid degradation of carbohydrates in the diet, reduction in rates of lipolysis and biohydrogenation, confirming the hypothesis of the action of micro-organisms cellulolytic about the biohydrogenation process ([Harfoot & Hazlewood, 1997](#)).

Polyunsaturated fatty acids can be offered in the diet with the use of oilseeds such as soybeans, canola, sunflower and linseed. These seeds present great interest by have owned high concentrations of lipids and desirable oil release rate, which

occurs when the animal does the breakdown of food by chewing ([Coppock & Wilks, 1991](#)).

Flaxseed in the diet of lactating cows

The flaxseed contains approximately 40% crude protein (CP) and 30% neutral detergent fiber (NDF), turning it into an excellent source of energy and protein to be added in the diet of lactating cows ([Petit, 2003](#)). Flaxseed is very rich in linoleic acid (C18:2), which is an important fatty acid secreted by the mammary gland and in humans is associated with the fight against free radicals ([Modesto et al., 2002](#); [Slots et al., 2009](#)); and anticancer properties, antiatherogenic, antidiabetic, immune response improver ([Pariza et al., 1999](#); [Lock & Bauman, 2003](#)).

Main anti-nutritional factor, the flaxseed presents the cyanide glycoside, which on enzymatic hydrolysis releases the hydrocyanic acid ([Feng et al., 2003](#)). The hydrocyanic acid concentration ranged between 365 and 550mg in 10 flaxseed cultivars in Canada ([Oomah et al., 1992](#)). In cattle, the lethal oral dose of hydrocyanic acid is 2 mg/kg/body weight, equivalent to 1, 3 g to an animal with body weight of 650 kg ([Conn, 1979](#)). Dairy cows receiving 10% of flaxseed in your diet, did not provide any metabolic problem with animals being unlikely that diets with less than 10% of the oleaginous bring negative effects or take the animal to death ([Brimer et al., 1983](#)).

There is still no consistent studies on the excretion of hydrocyanic acid in milk ([Tabeka et al., 1982](#)). However, taking into consideration that the lethal level of hydrocyanic acid to humans is of 0,5 to 3, 5 mg/kg of body weight ([Seawright, 1995](#)) it is not likely that the consumption of milk from cows fed flaxseed have any toxic effect.

Intake and digestibility of flaxseed

Studies are being conducted to determine the flaxseed intake and digestibility by lactating dairy cows, according to [Petit & Benchaar \(2007\)](#) the supply of 10 and 12% of flaxseed, in the dry matter, in the diet of lactating cows does not influence the consumption of dry matter in the prepartum period, but increases the dry matter consumption postpartum. On the other hand, [Petit \(2002\)](#) and [Secchiari et al. \(2003\)](#) found that 15% supply of flaxseed did not influence the dry matter intake of lactating cows.

Supplementation of dairy cows in early lactation diets containing 12 percent flaxseed increased digestibility of crude protein and ether extract, with a decrease in acid detergent fiber digestibility ([Silva et al., 2007](#)). Providing 10% of flaxseed for primiparous cows in milk cause increase in digestibility of the ether extract, without change in the digestibility of dry matter and neutral detergent fiber ([Oba et al., 2009](#)).

Fiber digestibility is linked to physical processing that flaxseed suffers, like the grind, which facilitates the access of ruminal microorganisms to particles of the add-in provided. According to [Gonthier et al. \(2004\)](#) the neutral detergent fiber digestibility of dry matter and was higher with the addition of 12.6% of ground flaxseed in relation to basal diet. For [Doreau et al. \(2009\)](#) the effect of flaxseed is dependent on the amount provided, due to the change in rate and low dry matter intake.

Most of the experiments conducted with the assessment of the effects of flaxseed on the feed intake and digestibility of dairy cows are short term, being evaluated the initial, middle, and final stages of lactation. Dairy cows from the 20th until the 30th week of lactation receiving supplementation have a higher consumption of fat dry matter than those who did not receive dietary flaxseed ([Goodridge et al., 2001](#); [Petit et al., 2002](#); [Secchiari et al., 2003](#); [Gonthier et al., 2005](#)).

The processing of oilseeds may affect the availability of the add-in in the rumen, changing the digestibility of nutrients and also consumption. Treatment with formaldehyde has this purpose. In this context, the supply of flaxseed treated with 10% formaldehyde did not change the dry matter consumption of flaxseed given to cows in early lactation ([Goodridge et al., 2001](#)). [Petit et al. \(2002\)](#) when dealing with flaxseed with 50% of formaldehyde also no observed effect on the dry matter intake of cows in the early stages of lactation.

Heat treatments are also used for the purpose of protecting the seeds of oilseeds the effects of ruminal degradation ([Mustafa et al., 2002](#)), and in this way increase the level of post ruminal digestion. However, treatments such as micronization (ultra-fine grinding) and extrusion (heating) had no effect on dry matter intake of dairy cows in early lactation when supplemented with 12% of flaxseed, and when compared to treatment without flaxseed ([Gonthier et al., 2005](#)).

Production of milk from cows fed with flaxseed

The effects caused by supplementation with flaxseed on milk production of dairy cows in early lactation seem to be neutral ([Petit et al., 2004](#)). According to [Petit \(2002\)](#) supplementation with 10.4% of flaxseed, in the dry matter of the diet, resulted in a 35.7 average production kg/milk/day in the first 16 weeks of lactation, which is similar to the production of cows fed with 11.7 and 18.4% soybean seed.

Cows receiving 5; 10;15% of flaxseed, with average production of 26, 9 kg/milk/day also showed no change in milk production ([Kennelly & Khorasani, 1992](#)). Similar results were found in dairy cows in the middle ([Petit & Gagnon, 2009; Petit et al., 2009](#)) and end of lactation ([Martin et al., 2008](#)) fed with up to 15% of flaxseed in your diet. [Secchiari et al. \(2003\)](#) to the supplement dairy cows with 1.8% of flaxseed, in the dry matter, also did not observe differences in milk production.

On the other hand, dairy cows in early lactation fed with 9.6% of whole flax seed, showed a decrease of 8.1% in milk production when compared to those of the control treatment ([Kennelly & Khorasani, 1992](#)). Already [Petit et al. \(2004\)](#) found that supplementation with 9.7% flaxseed resulted in a 29% increase in milk production in cows in early lactation, when compared to the diet without the addition of flax seed.

According to [Petit et al. \(2005\)](#) the crude protein content of whole flaxseed can be an important factor in the production of milk, as cows receiving flaxseed tend to have higher output than those who have not received the supplement, 24.9 and 20.3 kg/milk/day, respectively, and may be a result of the positive effects of protein on digestibility and feed intake.

Effect of changing of flaxseed

The physical alteration of the flaxseed, before feeding animal has positive effect on milk production, caused by the increased availability of ruminal microorganisms supplement particles. Thus, lactating cows receiving 10% of ground flax seed had 6.5% increase in production, when compared to the group receiving the whole seed ([Silva et al., 2007](#)). However, with the lowest levels of ground flax seed (1 or 1, 4 kg, accounting for 5.1 and 7.5% of the dry matter of the diet,

respectively), compared with the control treatment (without linseed) had no effect on milk production in cows in the middle third of the lactation ([Collomb et al., 2004](#)). Similarly, it wasn't observed change in milk production of cows in the final third lactation fed with 12.5% of ground flax seed ([Gonthier et al., 2005](#)).

The micronization is a dry heat treatment, which heats the food around 110 to 115°C, being used in cereal grains and oilseeds ([Petit et al., 1999](#)). The micronization process of flaxseed, rumen degradability decreases between 14 and 21%, but increases the digestibility intestinal level ([Mustafa et al., 2002](#)). However, although the heat treatment is effective for improving the contribution of post intestinal amino acids, flaxseed has similar effect on micronized milk production when compared with seeds in natura ([Gonthier et al., 2004](#)).

In the treatment with heat, the protein from oilseeds is surrounded by fat particles, keeping the partially protected from the ruminal degradation ([Khorasani et al., 1992](#)). However, this treatment had no effect on the biohydrogenation of the fatty acids from flaxseed ([Petit et al., 2002](#)) and did not affect the amount of amino acids post-ruminal ([Mustafa et al., 2003](#)).

The extrusion is also a heat treatment used for protection of the rumen microbial degradation protein. The extrusion of oil seeds tends to reduce protein in the rumen degradation and increase milk production ([Grumpelt & Ingalls, 1984](#)). However, in extruded linseed seeds is not effective in increasing the supply of amino acids post-ruminal ([Mustafa et al., 2003](#)), increasing the protein in the rumen, but reducing the same digestibility in lactating cows ([Gonthier et al., 2004](#)). Dairy cows in the middle of lactation, when fed with 12.6% of extruded linseed seed, in the dry matter, and compared to the control treatment (without linseed) 0.4% reduction in milk production ([Martin et al., 2008](#)). However, the treatment effect by extrusion for rumen degradability parameters of nutrient may vary according to temperature and the rate of passage of food, and can modify the response of the animal to the extruded flaxseed diet.

Composition of milk from cows supplemented with flaxseed

Overall dairy supplementation with flaxseed has no any effect on milk fat percentage. In this

context, the supplementation of cows, with 10.4% of flaxseed in early lactation ([Petit, 2002](#)), and 1.8% in late lactation linseed ([Secchiari et al., 2003](#)) not promoted effect on the fat content of milk when compared with cows fed with the control treatment without flaxseed.

Supplementation for cows in early lactation, in levels of 5 to 15% ([Kennelly & Khorasani, 1992](#)) and 11.1% ([Petit et al., 2009](#)) of inclusion of flaxseed, in the dry matter, not also promoted effect on the percentage of fat in the milk. In contrast, the middle third lactation cows, fed with diets of 5 levels, 10:15% of whole flax seed, showed milk fat concentration higher than the cows that received the diet supplement ([Petit & Gagnon, 2009](#)).

The effect of treatment with formaldehyde had no effect on production and percentage of fat in the milk of cows fed flaxseed when data were compared with the animals control diet ([Collomb et al., 2004](#)). As well as animals fed flaxseed treated with formaldehyde, in levels of 2.4 or 4.7% in dry matter, had no effect on the concentration of milk fat in comparison with the control diet without flaxseed ([Goodridge et al., 2001](#)).

Normally, the oils protected against rumen biohydrogen, increase the production of milk fat ([Ashes et al., 1992](#)). Thus, the powered by flaxseed oil reduces the fat content in milk, this is because the lower dry matter consumption and consequent decrease in fiber digestibility of foods ([Martin et al., 2008](#)). In addition, the high amount of trans fatty acids, particularly linoleic acid in the rumen, when the cows are fed with oil free, cause decrease in concentration of milk fat.

However, the natural protection of whole flax seed against the biohydrogenation does not promote any effect on the production of milk fat ([Petit et al., 2002](#)). In General, the reductions in levels are related to the elevation of unsaturated fatty acids.

The extrusion process of flaxseed, provided the level of 14.8%, for dairy cows in late lactation, promoted a reduction in fat content in milk of 4.11 to 3.53% ([Martin et al., 2008](#)). The extrusion increases the rate of release of oil from the seed, so fatty acids to the ruminal microorganisms, resulting in the decrease in concentration of milk fat ([Chilliard et al., 2009](#)).

The percentage of protein in milk appears to be affected by supplementation with flaxseed ([Kennelly & Khorasani, 1992](#)). However, the

supply of diets containing 7 to 12.4% of flaxseed for cows in early lactation had no effect on the concentration of milk protein when compared with the control diet ([Petit et al., 2004](#)). The supply of diets with 11.8% of flaxseed for cows between the 20th and 30th week of lactation, containing 16 or 18% crude protein, is not checked effect on milk protein concentration compared to animals not supplemented ([Petit et al., 2005](#)).

However, there was an increase of 2.98% to 3.81% in the concentration of protein in the milk of lactating cows fed with 10% of flaxseed ([Petit, 2002](#)). [Petit & Benchaar \(2007\)](#) working whit of flaxseed, on the basis of the dry matter, and changes were observed in the milk protein content when compared with animals receiving the control diet. According to [Kennelly & Khorasani \(1992\)](#) levels of 5 to 15% of flaxseed, has an effect on degradation of 3.21 to 3.13% in protein content in the milk. Corroborating, [Gonthier et al. \(2004\)](#) found that feeding dairy cows in late lactation with 12.5 and 12.7% of flaxseed, reduced the crude protein microbial flow into the duodenum, decreasing the synthesis of protein in milk.

These differences in protein content for each stage of lactation cows are probably moderate the responses of animals to additional fat added to the diet. The effect of supplementation with fat depends on the source of fatty acids provided to animals ([Schingoethe et al., 1996](#)). The concentration of protein in milk is often associated with fat supplementation, having positive effects on milk production ([Kennelly, 1996](#)).

Flaxseed processing has had little effect on the concentration of protein in milk. Cows fed with whole kernel or milled, in 10% of the dry matter of the diet were milk protein value ([Oba et al., 2009](#)). Micronization treatments and extrusion of the flaxseed had no effect on the concentration of milk protein of lactating cows when fed with 10% linseed, in dry matter ([Gonthier et al., 2005](#); [Martin et al., 2008](#)).

However, the milk protein showed significant change when the cows in late lactation received flaxseed treated with formaldehyde, at 17% in dry matter, showing an increase of 4.7% protein ([Petit et al., 2001](#)), suggesting that the animals had better nitrogen utilization of diet supplement. According to [Crawford & Hoover \(1984\)](#) the increase in concentration of protein in the milk of cows fed flaxseed formaldehyde-treated compared with untreated seed, is related to

the diversion of the use of the protein due to treatment.

The effect of flaxseed on concentration of lactose in the milk is still unclear. In this sense, the supply of diets with flaxseed from 7 to 15% in dry matter, for dairy cows in early lactation ([Khorasani & Kennelly, 1994](#)) and at the end of lactation ([Secchiari et al., 2003](#)) had no effect on the production of lactose when compared with the cows fed with flaxseed. In contrast, the percentage of dairy decreased when diets were used with 11.8% of flaxseed for cows in the middle of lactation ([Petit et al., 2005](#)), although there was no effect when provided micronized flaxseed ([Petit, 2002](#)). The concentration of lactose also is not affected by the physical processing of flaxseed when cows in early lactation received diets with 7 to 10% of ground flax seed ([Collomb et al., 2004](#)).

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