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Physical-mechanical properties of multinutrient blocks with different binders for goats and sheep intake

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ABSTRACT

Feed supplementation with multinutrient blocks (MB) for sheep and goats can be a viable alternative in the Brazilian semiarid region, and it is necessary to set an ideal hardness to obtain maximum feed efficiency. Therefore, this study aimed to evaluate the manufacture of MB using five binders: Portland cement, lime, kaolin, Portland cement + kaolin and lime + bentonite, at two percentages (7.5 and 10%) and two healing times (72 and 96 h). The experimental design was completely randomized in a 5 x 2 x 2 factorial scheme (binders, percentages and healing times, respectively), with five repetitions. Using lime in the MBs led to greater resistance in the specimens (208.53 kPa), as well as the greater percentage of binders (10%), ensuring higher hardness in the blocks. No change was observed in block hardness with the healing time, and a cure of 72 h is recommended. There was greater water absorption with the use of Portland cement and the use of kaolin and of lime + bentonite led to the lowest values of water absorption. The use of lime at 10% as binder and the 72 h healing time were shown to be the best combination in the manufacture of multinutrient blocks.

Palavras-chave:
absorção de água
dureza
resistência
suplementação alimentar

Propriedades físico-mecânicas de blocos multinutricionais com diferentes aglomerantes para ingestão por caprinos e ovinos

RESUMO

A suplementação alimentar com blocos multinutricionais (BM's) para caprinos e ovinos pode ser uma alternativa viável no semiárido brasileiro, necessitando-se definir a dureza ideal para se obter a máxima eficácia alimentar. Portanto, o objetivo do trabalho foi avaliar a confecção de BM's utilizando-se cinco aglomerantes: cimento Portland, cal, caulim, cimento Portland + caulim e cal + bentonita, em duas percentagens (7,5 e 10%) e dois tempos de cura (72 e 96 h). O delineamento experimental foi o inteiramente casualizado em esquema fatorial 5 x 2 x 2 (aglomerantes, percentagens e tempos de cura, respectivamente), com cinco repetições. A utilização da cal nos BM's promoveu maior resistência aos corpos de prova (208,53 kPa), garantindo maior dureza aos blocos. Não houve alteração na dureza dos blocos com o tempo de cura, recomendando-se uma cura de 72 h. Houve maior absorção de água com a utilização do cimento Portland e o uso do caulim e de cal + bentonita proporcionou as menores absorções de água. O uso da cal a 10% como aglomerante e o tempo de cura de 72 h demonstraram ser a melhor combinação na confecção dos blocos multinutricionais.

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Introduction

Sheep and goat farming in the Brazilian semi-arid region is mostly conducted by small farmers; the animals are used for local consumption and the surplus is sent for marketing (Farias et al., 2014). In this region, the animals are mostly raised extensively and depend on the Caatinga vegetation (Cordão et al., 2014). Alternatives such as the introduction of breeds specialized for the production meat and milk, or its crossbreeds (Cartaxo et al., 2014), and the adoption of genetic breeding programs and the selection of breeds or genotypes more adapted to the region can improve the zootechnical indicators of the herd. However, the main problem is the scarcity of grazing food in certain periods of the year (Goulart & Favero, 2011), where the nutrients contained in the pastures usually do not meet the demand of the animals.

Improvement of pasture, introduction of new forage species, utilization of native pastures associated with other components and/or ingredients in the feed of small ruminants can be viable alternatives to increase animal production, especially the supply of multinutrient blocks (MBs), which can improve carcass yield (Maza et al., 2016) and the production performance of goats and sheep, both confined and kept in the field (Freitas et al., 2003; Tobía et al., 2003; Arias-Margarito et al., 2012; Mubi et al., 2013; Aye, 2014; Tinga et al., 2014; Hernandez et al., 2015; Aye, 2016). MBs can be used in the periods of the year in which the pasture has no quality and/or is not in sufficient amount to meet the herd's requirement.

MBs are feed supplements rich in nitrogen, energy and minerals, supplied as a solid mass, which should not be consumed in large amounts due to its hardness (Hernández et al., 2014), which force the animal to lick or take small bites (Castro et al., 2017), ensuring slower consumption. The advantages of MBs also include low cost of production, easy supply of non-protein nitrogen, source of fermentable energy, easy release of nutrients to the animal (Mubi et al., 2013) and, since they do not require troughs, loss of nutrients by the wind is avoided, and they can be adequately distributed in the barn or in the field (Haro et al., 2011).

The use of binders in MBs mainly aims to agglutinate the materials and, in contact with water, to form a moldable and malleable paste, which becomes rigid and resistant after pressed and dried. Such hardness is intrinsic and depends on the type and concentration of binder used, and this incorporation allows to achieve important properties such as moldability, dimensional stability and adequate mechanical resistance.

Binders can interfere with MB properties, such as the digestibility of feed ingredients. Lime, kaolin, Portland cement and bentonite can prevent ruminal acidosis, since these are alkalinizing agents, causing stability of pH in the rumen and increasing nutrient consumption (Pina et al., 2010) and digestibility. Binders such as lime can improve the digestibility of straw and agricultural residues by causing the so-called alkali swelling of cellulose, due to the expansion of cellulose molecules with subsequent breaking of the hydrogen bonds.

In addition to the better nutrient use, the mixture allows for longer period of storage because lime, kaolin and Portland cement avoids the action of deteriorative microorganisms, also avoiding the presence of bees and mosquitoes, reducing the loss due to the reuse of leftovers in the trough. Tobía et al. (2003) observed a significant linear response in MB hardness as lime content increased, and Maza et al. (2016) cite a high MB consumption by sheep, attributed to the hardness of the blocks, due to the high proportion of molasses associated with binders such as lime.

Therefore, this study aimed to formulate multinutrient blocks with the addition of different binders at varied percentages and healing times and characterize them with respect to physical-mechanical properties.

Material and Methods

The study was carried out at the Laboratory of Rural Constructions and Ambiance of the Federal University of Campina Grande (UFCG), Campina Grande - PB, Brazil, using 200 specimens with 5 cm diameter, 10 cm height and weighing 300 g, evaluating the addition of five different binders: Portland cement (CP II - Z), lime, kaolin, Portland cement + kaolin and lime + bentonite, at two percentages (7.5 and 10%) and two healing times (72 and 96 h). The specimens were made using the ingredients listed in Table 1.

The ingredients to manufacture the specimens were separated and weighed, and molasses were initially mixed with urea in a concrete mixer for 5 min for homogenization. In a separate container, the other ingredients were mixed and then slowly added to the mixture. After all ingredients were put in the

Table 1. Percentage composition of the ingredients for the specimens in percentage and in kg

Base ingredients (kg)	Portland cement		Lime		Kaolin		Portland cement + Kaolin		Lime + Bentonite	
	7.5	10	7.5	10	7.5	10	7.5	10	7.5	10
	%									
Sugarcane molasses	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
Urea for livestock	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Common salt	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Mineral salt	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Soybean meal	22.0	20.0	22.0	20.0	22.0	20.0	22.0	20.0	22.0	20.0
Crushed corn	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
Calcitic limestone	3.5	3.0	3.5	3.0	3.5	3.0	3.5	3.0	3.5	3.0
Portland cement	7.5	10.0	-	-	-	-	-	-	-	-
Hydrated lime	-	-	7.5	10.0	-	-	-	-	-	-
Kaolin	-	-	-	-	7.5	10.0	-	-	-	-
Portland cement + kaolin	-	-	-	-	-	-	7.5	10.0	-	-
Lime + Bentonite	-	-	-	-	-	-	-	-	7.5	10.0

concrete mixer, they were homogenized for 10 to 15 min until the mass formed a consistent paste. The final mixture was weighed in containers (average weight = 300 g) and then the specimens were molded and compacted with an iron rod. The material was pressed in pneumatic press with 148.4 kg weight for 5 min. For each treatment, 10 specimens were made (Figures 1 and 2).

After these procedures, the specimens were removed from the molds, left at room temperature in the shade for 72 and 96 h to heal in open air, and then measured with a digital caliper to check for any irregular dimensions after healing. The analyzed variables were resistance to simple compression and water absorption, the former being determined with the aid of an Autograph universal tester, using 5 specimens for each treatment.

Figure 1. Mixture homogenized in concrete mixer

Figure 2. Specimens healing in open air

To evaluate water absorption, the specimens were weighed and remained for 7 days in sealed polystyrene foam boxes containing water. The procedures adopted to test the mechanical resistance of the specimens were those recommended by the NBR 5739 (ABNT, 2007). Water absorption was determined based on the NBR 9778 (ABNT, 2005).

The experimental design was completely randomized in 5 x 2 x 2 factorial scheme (five binders, two binder addition percentages and two healing times), with 5 replicates, totaling 20 treatments and 100 experimental units. The data of the variables measured in the experiment were subjected to analysis of variance by F test and means were compared by Tukey test at 0.05 probability level. The analyses were carried out using the statistical program Assistat 7.5 (Silva & Azevedo, 2016).

Results and Discussion

There was significant difference ($p < 0.05$) between treatments for the different types of binders, and the highest values of resistance in the MBs were obtained with the addition of lime. Treatments using Portland cement + kaolin and lime + bentonite did not differ from one another, showing intermediate resistance compared with the lime, and treatments with kaolin and Portland cement led to the lowest values and did not promote ideal agglutination of the blocks, which were brittle in comparison to the others (Table 2).

The higher resistance of MBs based on lime can be attributed to a lower complexity of reaction and to greater activation of its compounds in comparison to the other binders, combined with its other classic features, such as higher water retention capacity and greater workability of the mixture. Depending on the type of supplementation one intends to provide to the animal (mineral, protein-rich or energy-rich), the consumption of MBs may vary in order to meet its needs. Normally, mineral blocks lead to higher number of licks, whereas protein and protein/energy blocks cause higher number of bites. Castro et al. (2017), analyzing the consumption of MBs with different types of binders, percentages and healing times, observed higher number of licks by goats (335.0 on average), in comparison to bites (167.2 on average).

Binder percentage of 10% led to higher mean resistance ($p < 0.05$) compared with the percentage of 7.5%, contributing to a gain of 35% in the resistance, which demonstrates that

Table 2. Mean resistance to compression (kPa) as a function of the type of binder, binder addition percentage and healing time

Type of binder				
Portland cement	Lime	Kaolin	Portland cement + Kaolin	Lime + Bentonite
41.2 d	160.0 a	65.2 c	86.9 b	86.7 b
Binder addition percentage				
7.5%			10%	
74.8 b			101.2 a	
Healing time				
72 h			96 h	
85.5 a			90.5 a	

Means followed by the same lowercase letter in the row do not differ by Tukey test at 0.05 probability level better consistency is proportional to the increase in binder percentage (Table 2). Regarding the healing time, there was no significant difference ($p < 0.05$) between treatments, demonstrating that MBs can be made and supplied to the animals in a shorter time without affecting their integrity due to loss of resistance. Cordão et al. (2014) manufactured and used MBs with 10% of hydrated lime and other ingredients and used them in the supplementation for goats and sheep with healing time of 48 h.

Based on the significant difference between the types of binder and percentage of their addition in the blocks ($p < 0.05$) (Table 3), the addition of 7.5% of lime in the MBs led to higher resistance (111.48 kPa), promoting increments of 146.0% compared with the Portland cement (45.23 kPa) and 53.8% compared with the mean of the other three treatments, which were similar.

Mixtures based on Portland cement and kaolin at 10% did not differ from one another ($p > 0.05$) and caused lower resistance, as well as the mixtures based on Portland cement + kaolin and lime + bentonite, with moderate resistance. On the other hand, the exclusive use of lime led to higher resistance to compression, resulting in a 461% increase compared with the lowest resistance (Portland cement). Regarding the binder addition percentage, there was significant difference only for lime and lime + bentonite, with higher values at the percentage of 10%.

The results show that the use of lime can generate higher resistance in the MBs and the increase of 2.5% in the composition was able to cause an 87% increment in their resistance. A block with higher resistance can facilitate the manufacturing process and promote longer period of storage, with higher resistance to inclement weather during its use in the field. The increment in MBs resistance as lime proportion increased was also reported by Tobía et al. (2003), who observed that increments in lime levels in the formulation of the blocks led to an increasing linear response in the resistance, which indicates that it can replace Portland cement, promoting better conditions in the MBs and for animal welfare, since lime contains fewer substances harmful to ruminal microorganisms. Maza et al. (2016) cite that the use of lime associated with molasses increased consumption and promoted better carcass yield of the animals. Haro et al. (2011), using MBs with fermented nopal in their composition, 5% of Portland cement and 4% of lime, with healing time of 21 days, observed that the MBs were adequately consumed by growing lambs.

Regarding the healing time (Table 4), comparing the variation for the same binder, there was no significant difference ($p > 0.05$) between treatments, demonstrating that the MBs can be supplied to the animals earlier, with no need to subject them to a longer healing time. However, comparing the use of the different binders for the same healing time, highest and lowest values of resistance were caused by lime and Portland cement, respectively. It is worth highlighting the superiority of up to 4.5 times in the resistance caused by lime, at healing time of 96 h.

Arias-Margarito et al. (2012), using levels of molasses from 0 to 15%, urea (5%) and Portland cement (7.5%), found resistance of 400 kPa at 21 days, which is 2.5 times higher than the highest value found in the present study (162.9 kPa). Such difference lies in the time adopted to measure the resistance of the MBs, since Portland cement at the highest times tends to increase the binding power between the particles associated with it. Resistance influences consumption and depends on the proportion, type of binder and other ingredients, as well as on the healing time.

Kawas (2008) mentions that softer blocks can lead to a consumption greater than desired. Evaluating different levels of molasses in MBs, Freitas et al. (2003) used hydrated lime (7%) + phosphoric acid (10%) as binder and observed mean resistance of 616 kPa, approximately 3 times higher than the maximum value found here, using lime at 10% as binder (208.5 kPa). This can be justified by the presence of phosphoric acid in the composition and by the binder percentage, which was equal to 17% in total.

For water absorption (Table 5), significant difference ($p < 0.05$) occurred between treatments and the use of Portland cement as binder led to higher absorption compared with the others. Water absorption values caused by the use of lime and Portland

Table 3. Resistance to simple compression (kPa) of the specimens as a function of type of binder and binder addition percentage

Type of binder	Binder addition percentage (%)	
	7.5	10
Portland cement	45.2 cA	37.2 cA
Lime	111.5 aB	208.5 aA
Kaolin	71.8 bA	58.7 cA
Portland cement + Kaolin	82.2 bA	91.6 bA
Lime + Bentonite	63.3 bcB	110.1 bA

Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ by Tukey test at 0.05 probability level

Table 4. Resistance to simple compression (kPa) of the specimens as a function of the type of binder and healing time

Type of binder	Healing time (h)	
	72	96
Portland cement	46.2 aA	36.2 aA
Lime	157.0 aA	162.9 aA
Kaolin	64.3 aA	66.2 aA
Portland cement + Kaolin	74.5 aA	99.3 aA
Lime + Bentonite	85.7 aA	87.7 aA

Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ by Tukey test at 0.05 probability level

Table 5. Water absorption (g) of multinutrient blocks as a function of type of binder, binder addition percentage and healing time

Type of binder				
Portland cement	Lime	Kaolin	Portland cement + Kaolin	Lime + Bentonite
3.2 a	1.8 b	1.0 c	1.4 bc	1.2 c
Binder addition percentage				
7.5%			10%	
1.5 b			1.9 a	
Healing time				
72 h			96 h	
1.7 a			1.7 a	

Means followed by the same lowercase letter in the row do not differ by Tukey test at 0.05 probability level cement + kaolin did not differ; the use of kaolin and lime + bentonite led to the lowest values, and these treatments did not differ either.

There was an increase of 320% between the highest and lowest values of water absorption by the MBs, obtained using Portland cement and kaolin, respectively. Greater water absorption will lead to lighter and softer blocks, which can compromise their consumption and cause faster release of nutrients such as urea, possibly leading to intoxication of the animals.

The chemical properties of kaolin and bentonite as materials with absorption power promote chemical reactions that lead to saturation by water in the manufacture of MBs, making them moister than the others, even after the healing time. Greater water absorption with the use of Portland cement can be related to the fact that it does not react with the water contained in the molasses, requiring hydration before being mixed with the other ingredients. According to Sansoucy et al. (1988), to obtain ideal consistency of the blocks using Portland cement, it should be pre-mixed with water before being added to the mixture. This procedure ensures a uniform distribution of this binder within the blocks, which facilitates and improves their hardening.

Binder percentage of 10% led to higher water absorption by the MBs, which is justified because water is needed for the physical-chemical reaction of the additional 2.5% of binder in the mixture. Healing time alone did not cause statistical difference ($p > 0.05$) between treatments, evidencing that the MBs were already at maximum saturation at 72 h (Table 5).

The moisture content used in the formula of MBs is highly variable, and water may or may not be added to their composition. Tinga et al. (2014) made MBs using 5% of water, molasses (30%), urea (10%), salt (5%), Portland cement (15%) and corn meal (35%) and found that the consistency of the manufactured blocks did not differ from that of commercial blocks, allowing easy handling and good distribution to the animals. There are many components used to formulate MBs, and the raw materials used which do not have the same morphological structure, equal capacity of absorption (hygroscopicity) or even the same moisture equilibrium, can change the characteristics of the blocks.

Among the binders, the percentage of 7.5% led to higher water absorption by the MBs made with Portland cement and lime, which significantly differed ($p < 0.05$) from the other treatments, and at 10% the highest absorption was caused by the use of Portland cement (Table 6). This is justified by the fact that Portland cement has a larger surface of absorption than the other binders, i.e., it has finer particles and consequently greater number of particles in contact with water.

Table 6. Water absorption (g) by the specimens as a function of the type of binder and binder addition percentage and healing time

Type of binder	Binder addition percentage (%)		Healing time (h)	
	7.5	10	72	96
Portland cement	2.3 aB	4.0 aA	2.8 aB	3.6 aA
Lime	2.1 aA	1.4 bB	1.7 bA	1.8 bA
Kaolin	1.0 bA	1.0 bA	1.2 bA	0.8 cA
Portland cement + Kaolin	1.2 bA	1.6 bA	1.6 bA	1.2 bcA
Lime + Bentonite	1.0 bA	1.4 bA	1.2 bA	1.2 bcA

Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ by Tukey test at 0.05 probability level

For the healing time (Table 6), significant difference ($p < 0.05$) occurred only in MBs made with Portland cement, which led to higher water absorption at 96 h. Among the binders, at the two healing times, greater water absorption was caused by the Portland cement and lowest water absorption was caused by the use of kaolin at 96 h. At this healing time, there was a difference of 345% in the water absorption between MBs made with Portland cement and with kaolin. During the storage, quality can be compromised in very wet blocks, because they can deteriorate more easily. Finer elements require more moisture, due to their high capacity of absorption and large surface area exposed to the environment.

An important fact that corroborates the reduced mechanical resistance and high water absorption of the MBs made with Portland cement is that, due to the significant specific surface of its particles, it needs to be fully hydrated to produce silicates and aluminates responsible for the gain of resistance, compacity and other properties. If there is not a full hydration, the MBs may still contain portions of Portland cement still intact which would not participate in the gain of resistance and, after the contact with water in the tests of absorption, would tend to absorb it in larger amount due to their high natural hygroscopicity.

Conclusions

1. Exclusive use of lime as binder led to higher resistance to simple compression and lower water absorption by the multinutrient blocks.
2. Lowest values of compression and highest mean water absorption occurred in blocks made with Portland cement without previous hydration.
3. Mixed with bentonite, the resistance of the lime decreases by almost 50%.
4. Higher binder percentage improved the quality of the multinutrient blocks.
5. Healing time of 72 h is sufficient to impart resistance and hardness to the multinutrient blocks.

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