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Review

Ruminant Lick Blocks, Particularly in China: A Review

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Abstract: A lick block (LB) is a solidified mixture of molasses, urea, minerals, filler, coagulant and binder that is supplemented to livestock mainly in relatively extensive rearing systems. It provides nutrients, such as soluble sugars, proteins, minerals and vitamins to balance dietary intake and can improve rumen fermentation and facilitate digestion and absorption of nutrients. These supplements improve livestock production, reproduction and carcass quality. In addition, LB can partially replace concentrate, serve as a delivery vehicle for additives such as enzymes and drugs and mediate the distribution of grazing livestock. This paper classifies and analyzes representative research; discusses the types, ingredients and current status of the utilization of LB; and systematically reviews the processing technology, quality assessment, influencing factors of intake, action mechanism and application. This review can provide a basis for the development, popularization and application of novel LB products.

Keywords: ruminant; lick block; processing technology; quality estimation; performance

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1. Introduction

Cattle and sheep breeding systems in China include grazing, grazing combined with stall-feeding, and stall-feeding. Over-grazing has degraded the grassland. Consequently, currently, there is a grazing prohibition period in many pastoral areas in China [1]. Only withered grass is available for up to 7 months each year, and, at this time, cattle and sheep consume mainly roughage based on hay, straw and silage. Either no dietary supplements or minor supplements of concentrate are offered to the animals. The quantity and quality of the forage are poor, resulting in substantial bodyweight losses in ruminants and reduced productivity and reproduction [2,3]. Because of land constraints due to urbanization, degradation of pastures and conversion of grazing land to cropland, cattle and sheep are more dependent on concentrate, which increases the cost of raising them. Under the impact of the COVID-19 epidemic, the output of domestic and foreign feed ingredients decreased, and prices rose sharply. This increased the competition between people and animals for grain and limited the supply of feed resources and animal products. Therefore, the offering of lick blocks (LBs) to ruminants is a viable alternative to overcome the previously mentioned issues.

LBs provide continuous nutrients for rumen microorganisms and host animals, modulate the rumen environment, improve rumen fermentation, facilitate digestion and absorption of nutrients and compensate for insufficient and/or unbalanced nutrient intake [3–6]. The supplement can improve livestock production, reproduction and carcass quality [2,3,7–11] and increase the income of farmers. The inclusion of agro-industrial by-products in LB reduces the use of concentrates and feeding costs and alleviates the problem of competing with humans for grain [12,13]. LB can also be used as carriers of additives such as enzymes and drugs to improve the digestibility of low-quality roughage and treat and/or prevent animal diseases [14–16]. However, it is important to be aware that LBs can transmit diseases and, therefore, proper precautions should be taken [17,18]. In grazing livestock, LBs not only play a nutritional role but can also mediate the distribution of the livestock and reduce grassland degradation caused by over-grazing [19,20]. LBs have the advantages of a simple manufacturing process, low production cost, convenient storage and easy transportation. It has been used in all continents, covering more than 60 countries [21], and its application has been expanded from ruminants to non-ruminants such as pigs [22], rabbits [23] and horses [24]. This paper discusses the current status of LB use and provides theoretical and scientific bases for improving its production and utilization.

2. Types of Lick Blocks

The types of LB are varied, and there is no consistent naming standard. According to their functions, LBs can be divided into two types. The first type, which is called a nutrient block (NB), supplies essential needs such as energy, protein, minerals and vitamins. At present, most NBs are composed of a variety of ingredients. Therefore, NBs are also called multi-nutrient blocks, among which urea molasses multi-nutrient block is common [25]. The second type, which is called a mineral block (MB) [26], salt block or mineral salt block [27], supplies mainly minerals. MB is made with mainly salt as a carrier, and the salt content usually exceeds 65% (Table 1, MB_1 and MB_2), while most NBs are made with molasses as a carrier (Table 1, NB_5 and NB_{17}).

3. Ingredients Composition and Current Status of Lick Block Usage

There are many ingredients in LB, including molasses, urea, bran (wheat bran, rice bran), cake (soybean meal, cottonseed meal, olive cake, sunflower meal), grain seed (corn, soybean, barley, fava bean) and unconventional feeds (moringa oleifera leaf, citrus pulp, tomato pulp, cucumber waste, mango waste, avocado waste, grape marc, cactus waste, corn distiller's dried grains with solubles, bagasse and poultry manure), cement, quicklime, salt and minerals. The ruminant species and its physiological status determine the type of LB to be offered. The availability, nutritional value, costs, tractability and overall impact on the quality of LB determine the choice of ingredients. For the most efficient use and desired effect, LB formulation should follow the following principles:

1. Clarify the purpose for production;
2. Determine the nutrient requirement of the animal;
3. Determine the type and proportion of components; and;
4. Constantly adjust and optimize the ingredients.

3.1. Urea

Urea is the most widely used non-protein nitrogen (NPN) compound in ruminant rations [28] and has the advantages of high nitrogen (N) content, low cost and substantial feeding effect [28,29]. The rumen microbiota can utilize both true protein and NPN [30] to synthesize microbial protein required for ruminant growth, so more high-quality protein can bypass the rumen and save protein resources [31]. However, the direct utilization of urea by ruminants is limited by poor palatability. The addition of molasses and other attractants to LB disguises the bad flavor of urea; however, urea intake should be monitored to prevent ammonia poisoning. The addition of urea should not exceed 13% of the weight of the NB (Table 1) and should not be offered to monogastrics and young ruminants. In sheep, dry matter intake (DMI) with the addition of urea in LB is higher than untreated hay and hay treated with a urea solution [32]. By adding a urea–calcium sulfate mixture, urea in LB can be released slowly, and beneficial results were reported in both in vivo (Table 1, NB_1) and in vitro (Table 1, NB_2) studies in beef cattle and buffalo [33,34]. Other methods for slow-release urea include adding formaldehyde-treated urea, grease-protected urea and polymer-encapsulated urea to the LB [35].

3.2. Molasses

Molasses, also known as syrup, is a by-product of the sugar industry and is a high-quality energy resource that is often used in ruminant production [36]. Molasses usually refers to high-yield sugarcane molasses, but there are also beet, citrus and date molasses [37]. There were 60 million tons of sugarcane and beet molasses produced worldwide in 2007 (FAO statistics do not differentiate between both origins) [37]. The main components of molasses include natural sucrose, glucose and fructose, with a total sugar content of 45 to 51% [38]. The dry matter (DM) content is 72 to 79%, and it contains 4 to 10% crude protein (CP) content, and 1 to 2% ether extract (EE) content [38]. Molasses requires an infrastructure for storage, transport and handling, so feeding liquid molasses is difficult for smallholders or nomadic pastoralists. Including molasses in LB not only facilitates feeding molasses but also makes it more cohesive. The cohesiveness depends on the sugar content, known as the Brix value (BV), which is expressed as the percentage of sugar content, by weight, of molasses [36]. In order to ensure proper hardening of the LB, the BV of the molasses should be at least 85% [39]. Because molasses is expensive, LBs without molasses have been developed in many countries [40,41].

3.3. Minerals

Minerals, in addition to protein and energy, are important elements that play vital roles by serving in structural, physiological, regulatory and catalytic functions in animals [27,42]. Mineral deficiencies can have negative effects on animal health, immune system and fertility [43], and severe deficiencies can even lead to death. The inclusion of minerals in LB compensates for deficiencies in the diet to meet the requirement of the animal, especially for rumen fermentation. For example, sheep grazing in the cold season are provided with LB rich in sodium, phosphorus, copper and selenium [44]. Grazing livestock in N fertilized pastures are provided with LB rich in copper [45]. Ruminants consuming low-quality forage are provided with LB rich in various mineral elements. The addition should be in accordance with authoritative nutritional requirement standards such as NRC or ARC and then combined with any specific needs of the animals. For example, cattle are provided with LB rich in bicarbonate to prevent and treat subacute rumen acidosis [27,46], and dairy cows are provided with LB rich in selenium, zinc and copper to prevent mastitis [27,47]. Sodium in LB is generally in the form of low-cost salt, which mediates LB intake, acts as an antiseptic and fulfills a nutritional role [17]. Trace minerals are often in additive premix, which provides iron, manganese, zinc, copper, selenium, iodine and cobalt. Organic mineral sources such as oyster shell, eggshell and bone meal can also be used [48,49].

3.4. Filler

Fillers, which comprise 18 to 94% of NB (Table 1), play a structural support role. Pure MB, however, does not require filler (Table 1, MB_1 and MB_2). Fillers are generally classified into bran, cake and grain seeds. The most commonly used is wheat bran, which comprises 4 to 32% of NB (Table 1). Wheat bran is a by-product of wheat flour processing, and the annual output in China is approximately 32 million tons [50]. Wheat bran in NB not only provides structural support but is also rich in nutrients. The quality of wheat bran has an impact on the structure, shape and hardness of LB. The coarser the wheat bran, the better the structure of the LB. However, the hardness of LB decreases if the proportion of wheat bran is too high or if rice bran is used instead of wheat bran [8,51]. Sunflower meal, barley flour, olive cake, fava bean flour, corn distiller's dried grains with solubles (Table 1) and *Tithonia diversifolia* leaf powder [52] can replace wheat bran, either partially or completely.

3.5. Coagulant

The coagulant, also known as the curing agent, is used mainly to increase the hardness of LB and limit excessive intake by animals [51]. There are many types of coagulants for LB, including calcium oxide, magnesium oxide, cement and quicklime, with cement and quicklime commonly used today (Table 1). Portland cement and ordinary Portland cement are the most common cement, but slag cement, pozzolan cement and fly ash cement are also used [4]. The main components of cement are silica and quicklime, with lesser amounts of oxides of aluminum, magnesium, sulfur, iron and potassium [53]. Mubi et al. [54] reported that cement contained 26 ppm iron, 180 ppm manganese and 139 ppm magnesium. Therefore, cement not only acts as a curing agent but also provides minerals. Some nutritionists and extension workers stated that cement might have negative effects on animals [39], but Hu [4] and Xu [55] reported that the addition of 5% and 8%, respectively, had no adverse effects (Table 1, NB_7 and NB_9). Asaolu [56] compared the inclusion of 15, 17 and 20% cement and concluded that 15% cement had the same or better curing effect than the other two. Excessive cement may result in an LB that is too hard.

3.6. Binder

Binder is important to bind the bulk ingredients. Bentonite, which is often used (Table 1), is a common smectite clay mineral that is composed mainly of montmorillonite. It has a large specific surface area, cation exchange capacity and adsorption capacity. Bentonite has the advantages of strong binding, non-toxicity, enormous reserves, wide distribution and low price [51]. It is divided into sodium bentonite and calcium bentonite, according to its interlayer ions [57], and its inclusion is generally 8 to 30% of LB (Table 1). Excessive bentonite may reduce its ability to waterproof the LB to a point where it can be easily nibbled by animals [58]. In addition, bentonite contains some macro and trace minerals, including potassium, sodium, magnesium, aluminum, iron and zinc [59]. It was reported that adding 0.1% to 0.3% to the diet for beef cattle can improve average daily gain (ADG), cold carcass weight, marbling score and quality grade without any adverse effects [60]. In an in vitro gastrointestinal tract study, bentonite adsorbed mycotoxins such as aflatoxin, zearalenone and deoxynivalenol [61], thereby inhibiting or reducing the absorption of mycotoxins.

Table 1. Formulae and chemical composition of lick blocks.

Items	Formulae [1]																		
	NB_1	NB_2	NB_3	NB_4	NB_5	NB_6	NB_7	NB_8	NB_9	NB_{10}	NB_{11}	NB_{12}	NB_{13}	NB_{14}	NB_{15}	NB_{16}	NB_{17}	MB_1	MB_2
Ingredient (%)																			
Urea	-	-	10	10	5	5	13	10	10	0.4	0.4	-	2	8	8	8	-	-	-
Molasses	38	38	10	20	40	25	20	20	25	2.1	5.16	22	10	12	12	12	52	5	12
Wheat bran	-	-	-	4	-	32	18	-	27	20	22.1	-	-	-	-	-	-	-	-
Rapeseed meal	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cottonseed meal	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	-	-	-
Sesame seed meal	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sunflower meal	-	-	-	-	-	-	-	-	-	25.8	25	18	-	-	-	-	-	-	-
Wheat flour	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corn flour	-	-	15	-	-	-	-	-	-	10	22	-	-	-	-	-	-	-	-
Dry hay meal	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distillery dry grain soluble	-	-	-	-	-	-	-	-	-	-	-	-	-	24	21	21	-	-	-
Cereal straw	-	-	-	-	-	-	-	-	-	9	8	-	-	-	-	-	-	-	-
Rice bran	30	30	-	-	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bypass protein meal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-
Barley grain flour	-	-	-	-	-	-	-	-	-	-	-	32	20	-	-	-	-	-	-
Fava bean flour	-	-	-	-	-	-	-	-	-	-	-	-	40	-	-	-	-	-	-
Olive cake	-	-	-	-	-	-	-	-	-	-	-	12	10	-	-	-	-	-	-
Mango pulp and peels	-	-	-	-	-	-	-	-	-	29	-	-	-	-	-	-	-	-	-
Avocado pulp and peels	-	-	-	-	-	-	-	-	-	-	14.8	-	-	-	-	-	-	-	-
Palm soap	-	-	-	-	-	-	-	-	-	1.2	0.04	-	-	-	-	-	-	-	-
Tallow	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NaCl	1	-	7	20	2	4	6–10	30	10	-	-	6	6	8	5	5	10	65	66
$CaHPO_4$	-	-	-	12.5	-	-	-	10	-	-	-	-	-	-	-	-	-	18	-
$CaCO_3$	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	-	-
Sulfur	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Na_2SO_4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
Bone meal	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limestone	-	-	-	-	-	-	-	-	-	-	-	-	-	8	8	8	-	-	5
Mineral premix	1	1	-	8.5	-	5	26–30	5	10	-	-	-	-	15	15	15	-	-	8
Vitamin–mineral premix	-	-	-	-	-	-	-	-	-	0.5	0.5	3	3	-	-	-	-	2	-

Table 1. *Cont.*

Items	Formulae [1]																		
	NB_1	NB_2	NB_3	NB_4	NB_5	NB_6	NB_7	NB_8	NB_9	NB_{10}	NB_{11}	NB_{12}	NB_{13}	NB_{14}	NB_{15}	NB_{16}	NB_{17}	MB_1	MB_2
CaO	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	3	-	-	-
MgO	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	4	-	-	-
Quicklime	-	-	-	5	8	-	-	-	-	-	-	7	9	-	-	-	-	-	-
Cement	9	10	-	-	-	-	5	-	8	-	-	-	-	-	-	-	-	-	-
Bentonite	-	-	30	20	-	-	8	-	10	-	-	-	-	13	9	9	-	-	9
Dolamite	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-
Urea–formaldehyde resin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Mold release agent	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5	-
Urea calcium sulfate mixture	18	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fenbendazole	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.05	-	-
Yeast culture	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-	-
Cellulase	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-
Chemical composition (g/kg, DM)																			
DM	780	730	-	-	-	928	-	-	-	889	926	790	760	764	774	768	-	-	-
Ash	296	243	-	-	-	215	-	-	-	-	-	269	260	246	226	231	-	-	-
CP	350	355	430	-	160	355	-	-	-	189	173	104	132	428	502	464	-	-	-
EE	24	-	-	-	-	7	-	-	-	31	39	3	3	-	-	-	-	-	-
NDF	270	146	-	-	-	161	-	-	-	422 [2]	410	167	127	202	192	183	-	-	-
ADF	211	94	-	-	-	102	-	-	-	194 [3]	244	80	24	82	78	81	-	-	-
Ca	-	-	-	-	-	54	-	-	-	-	-	-	-	55	55	56	27	-	-
P	-	-	-	-	-	20	-	-	-	-	-	-	-	19	19	19	13	-	-

[1] NB_1: Cherdthong et al. [33], NB_2: Cherdthong and Wanapat [34], NB_3: Dong et al. [2], NB_4: Li [8], NB_5: Vu et al. [7], NB_6: Bipate [11], NB_7: Hu [4], NB_8: Dong et al. [62], NB_9: Xu [55], NB_{10}: de Evan et al. [13], NB_{11}: de Evan et al. [12], NB_{12} and NB_{13}: Molina-Alcaide et al. [63], NB_{14}, NB_{15} and NB_{16}: Can [14], NB_{17}: Olmo et al. [64], MB_1: Xing [65], MB_2: Liu [66]; [2] aNDFom: neutral detergent fiber with heat-stable amylase and expressed exclusive of residual ash; [3] ADFom: acid detergent fiber expressed exclusive of residual ash.

4. Manufacturing Technology of Lick Blocks

The casting and pressing methods are mainly used in manufacturing LBs [67,68]. In the casting method, also known as the chemical pouring method, the mixed ingredients for LB are poured into a mold, and then the mold is removed to allow the LB to dry [67]. This is called the hot process, which depends mainly on the binding action of heated molasses. In 1986, the FAO Feed Resource Group modified the "hot process" to the "cold process", where heating the ingredients was not required and coagulants and binders such as calcium and magnesium oxide, calcium hydroxide, di-ammonium phosphate, cement and bentonite were used [69]. This simplified the manufacturing process, as heating equipment is not needed. In the pressing method, also known as the extrusion molding method, the bulk ingredients for LB, except for coagulants and binder, are poured into a mold and then extruded by an external pressing device. The mold is then removed to allow the LB to dry. The casting and pressing methods differ in the binding; the casting method uses coagulant and binder, while the pressing method uses external force. Compared with the pressing method, the casting method employs simple equipment and production processes but has a long molding time, loose texture, unstable quality and low production efficiency [70]; consequently, the pressing method is more suitable for large-scale production.

The LB technology was introduced into China in the 1990s. In the early stages, NB was produced mainly by a combination of casting and pressing methods. Based on the pressing method, appropriate amounts of coagulant and binder were added by the casting method. For example, Li [1] used 2% cement as coagulant and 10% palygorskite as a binder, and hydraulic pressure of 8 to 9 MPa to produce NB. The manufacturing of MB was determined according to the components. Pure MB adopted the pressing method [71], while non-pure MB used coagulant and binder and then was pressed [72]. The pressing method of LB changed from the early manual and manual hydraulic pressing to the commonly used electro-hydraulic pressing. Ultimately, a fully automatic LB production system emerged [73]. The choice of production mode is related to the purpose and economic status of the livestock raiser. When the cost of labor is low, and the quantity of LB required is modest, or when the LB is produced on the farm, the LB is made by hand; otherwise, a concrete mixer is commonly used for mixing the ingredients [21].

5. Quality Evaluation of Lick Blocks

As a product, LB does not have a firm set of criteria for evaluation. The quality of LB is assessed mainly by parameters such as hardness, density and waterproofness, and phenotypic traits such as surface roughness, crack size, color and smell. In addition, chemical analysis, in vitro rumen fermentation and animal feeding trials are also considered (Table 2). The hardness of LB has important implications for storage, transport and animal intake. Sansoucy [74] divided the hardness of LB into five grades, which is still used at present, as it is simple and cheap, but it is subjective and not scientific (Number 1, Table 2). A more accurate method to determine the hardness of LB is by penetrometer (Chattillon, NY, USA. GAUGE R. -CATL 719-20), which measures the pressure required to insert a rod into the LB to a predetermined depth [54]. Hardness is then calculated according to Equation (3) in Table 2. In China, crushers are commonly used to measure the crushing strength of LB, which is also known as compressive strength [75] and represents the hardness of LB (Equation (2), Table 2). Many factors that affect the hardness of LB were considered, including pressing pressure [4], the salt ratio [65], type, ratio of binder to coagulant [58], curing time and the proportion of the bulk ingredients [76]. The hardness of LB is greatest by using the casting plus the pressing method (41.4 kg/cm^2) [1], then the pressing method (30 kg/cm^2) [77] and finally the casting method (2.5–4.5 kg/cm^2) [78]. The density of LB determines its hardness, which is calculated by Equation (3) in Table 2. The level of waterproofness of LB, usually measured by the degree of deliquescence, is important as it affects its storage, transportation and service life. The phenotypic traits of LB can be assessed by visual inspection by experienced personnel (Number 8, Table 2). The nutritional value and storage stability of LBs are evaluated by measuring the contents of nutrients and anti-nutrients and the disappearance of nutrients after long-term storage (Number 9, Table 2). Following the above evaluations, the nutritive value of LB can be examined by in vitro rumen fermentation and animal feeding studies (Numbers 10 and 11, Table 2).

Table 2. Methods of quality assessments of lick blocks.

No.	Items	Assessment Methods	Ref.
1	Hardness	Pressing by hand	[48]
2		Dent depth of LB after continuous impact of hardness tester	[79]
3		Hardness (kg/cm^2) = Pressure/Indenter cross-sectional area [Equation (1)]	[54]
4		Crushing strength (kg/cm^2 or kN/mm^2) = Crushing load/Bearing area [Equation (2)]	[1]
5	Density	Density (g/cm^3) = Weight/Volume [Equation (3)]	[65]
6	Waterproofness	Deliquescence (%) = (Weight before immersion in water—weight after immersion in water)/Weight before immersion in water [Equation (4)]	[75]
7		Vertical insertion distance of iron wire after immersion in water	[66]
8	Phenotypic trait	Surface roughness, crack size, color, smell	[4]
9	Chemical analysis	Contents of nutrients and anti-nutrients	[80]
10	In vitro rumen fermentation	Gas production parameters, fermentation parameters	[81]
11	Animal feeding studies	Productive performance, reproductive performance	Table 3

6. Factors Influencing Lick Block Intake

The measurement of LB intake is required to determine whether the LB meets the needs of animals. It is important to feed LB accurately, which can be measured by an electronic feeder [82] or accelerometer [26]. Ruminants licking an LB is due to their "nutrition wisdom", which stimulates them to seek and consume salt at a level that meets or exceeds their requirement for sodium [83]. Therefore, MB controls the intake mainly by manipulating the salt level. The proportion of salt in NB is relatively small, and feed attractants such as molasses, citric acid or corn starch are generally added to entice animals to lick the LB. However, this does not necessarily mean that the higher the salt content in the LB, the greater the intake, as the intake is also affected by a combination of other factors. As demonstrated by Chládek and Zapletal [84], grazing and stall-fed beef cattle select relatively less LB with high salt content when sodium deficient, but prefer LB for an optimal calcium–phosphorus ratio. Ranches et al. [67] reported that intake of LB was 40% lower with mineral additives than without the additives. They also reported that calves preferred copper, zinc and manganese from hydroxyl chloride sources than from organic and sulfate sources, possibly due to feed aversion, as mineral additives from organic and sulfate sources have a "metallic-like" taste. Aubel et al. [85] reported that consumption of LB appeared to decline over time as the forage transitioned from winter dormancy to active spring growth. Moriel et al. [86] reported that beef cattle fed a low-quality hay-based diet had a high LB intake in the first week that remained unchanged until the sixth week. The results of both studies indicated that there was an adaptation period for animals to lick LB, and the LB intake was related to the quality of the basal diet. In addition, the cleanliness of the LB surface also affects intake [87]. The variation in LB intake is large, ranging from 12.3 g/d to 500.0 g/d (Table 3), and depends on body size, physiological condition, production stage and nutrient requirements of the animals. In addition, the hardness of LB affects LB intake. Hu [4] demonstrated that the pressing pressure of LB was correlated positively with the hardness of LB within a certain pressure range, and the hardness of LB was correlated negatively with the LB intake. In summary, the LB intake of animals is affected mainly by the composition and quality of LB and the basal diet, surface cleanliness of the LB, animal species and animal physiological status.

7. Action Mechanisms and Application Effect of Lick Blocks

The function and health of the rumen depend mainly on rumen microorganisms [88]. The growth and reproduction of rumen microorganisms depend on the rumen not only to provide appropriate temperature, osmotic pressure, pH and anaerobic conditions but also for fermentable carbohydrates, proteins, minerals, vitamins and other nutrients. When the nutrients are insufficient or unbalanced to meet the requirement of rumen microorganisms, the LB can continually balance the supply of needed nutrients, stimulate saliva secretion, improve the activity of rumen microorganisms, alter the community structure and quantity of rumen microorganisms, improve the digestive enzyme activities of the gastrointestinal tract and modulate the rumen environment [3,5,6]. The enhancement of rumen fermentation improves digestibility of the diet, increases the passage rate of roughage through the gastrointestinal tract, reduces the degree of rumen fill and increases dietary intake and, therefore, nutrients [4,89], which aids in fulfilling the requirements of rumen microorganisms and the host (Figure 1).

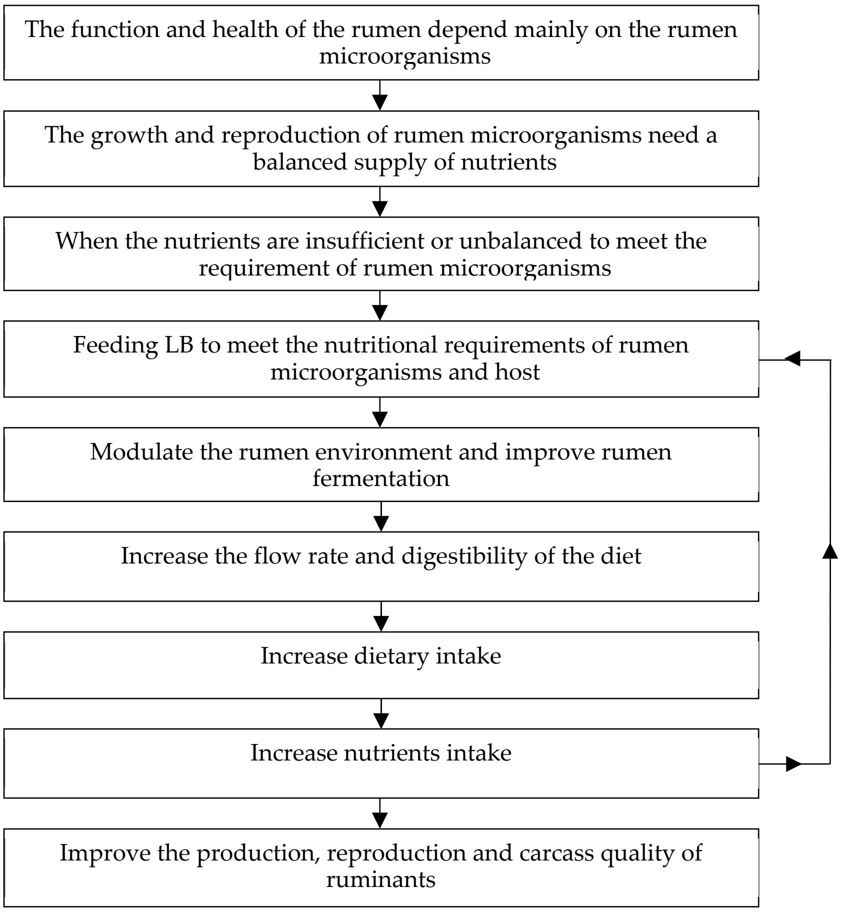

Figure 1. Action mechanisms of lick blocks as nutritional supplement.

7.1. Lick Blocks Affect the Productive and Reproductive Performances of Ruminants

To date, numerous feeding trials have been conducted to evaluate the effect of LB on the productive performance of ruminants. Supplementary LB has a positive effect on the weight gain or reduction in weight loss in yaks, Tibetan sheep, beef cattle, buffaloes, sheep and goats (Table 3). The ADG of grazing yak calves supplemented with MB_1 was 60.8% greater in the cold season [90] and 18.3% greater in the warm season [91] than control calves. The weight loss of sheep grazing withered grass and supplemented with NB was substantially less than control sheep [92], while the ADG of beef cattle fed a TMR diet supplemented with NB was 8.0% greater than control cattle [93]. Therefore, LB has the greatest effect on livestock consuming a poor quality or an insufficient basal diet. In addition to having a positive effect on body weight, LB also improves milk yield and quality and wool yield (Table 3) and can improve reproduction in male and female livestock. Energy, protein and minerals in LB enhance the development of the reproductive system, increase the level of reproductive hormones in the serum of postpartum females, promote the development of reproductive organs, shorten the calving interval, regulate the estrous cycle, reduce the number of matings and increase calving rate (Table 3). More nutrients are supplied for fetal development, and birth weight and survival rate of newborns are increased when pregnant females are offered LB, while the quantity and quality of semen are improved when males are offered LB (Table 3).

7.2. Lick Blocks Can Partially Replace Concentrates

NB can partially replace concentrates in the dietary ration. Carlos et al. [81] examined in vitro fermentation of avocado and mango wastes (peels and a pulp:peels (PP) mixture) with goat rumen fluid and the potential of including the PP mixture in NB for goats. The wastes had high moisture content, high levels of non-structural carbohydrates from mango and high levels of fat from avocado. A PP mixture of each fruit was suitable for LB by including nutrients from other sources. When a PP mixture of avocado and mango replaced 50% of alfalfa hay, in vitro fermentation parameters and gas production were similar to those of alfalfa hay. These results suggested that mango and avocado wastes can be included in NB for goats.

Subsequently, de Evan et al. [12,13] replaced 50% of concentrate fed to dairy goats with NB_{10} and NB_{11} from mango and avocado waste by-products. This dietary modification had little impact on nutrient intake and digestibility and the milk yield and composition of goats (Table 3). In addition, when NB based on tomato or cucumber wastes replaced 50% of concentrate in diets based on alfalfa hay, feeding costs decreased by 32%, fermentation parameters were improved, the relative abundance of methanogenic archaea increased and digestible energy was not affected, but N retention was reduced by up to 29% in non-productive goats [94]. When NB based on olive cake replaced 50% of the concentrate in feed to goats, nutrient utilization, N value of the diet and milk composition were not affected. The decrease in milk yield in these goats was compensated by a better quality of milk, decreased cost of feeding and the environmental advantage of including by-products in NB [63]. The common characteristics of these agro-industrial by-products are large seasonal yields, high moisture content and unbalanced main nutrients, which need to be used quickly before spoiling. Using these high moisture agro-industrial by-products in LB reduces environmental pollution, the use of concentrate and feeding costs and alleviates the problem of competition between people and animals for grains. Currently, such LBs of agro-industrial by-products are mostly for small ruminants in the Mediterranean region. The production of LB based on cost-effective alternative feed resources and local feed resources should be developed further in the future, as it can help ensure the sustainability of animal husbandry.

7.3. Lick Blocks Can Be Used as a Carrier for Additives

With the continuous development of LB technology, more additives, including enzymes, drugs, growth-promoting factors, chemical reagents, flavors and preservatives are being incorporated. Ainscough et al. [95] examined the stability of adding phytase and xylanase in LB under different temperature conditions. At 60 °C, phytase and xylanase can be added, while at 100 °C, xylanase can be added to LB without adverse effects. These results could lead to testing other enzymes in the future. Compared with steers fed conventional LB (NB_{14}, Table 1), steers fed LB with added yeast culture (NB_{15}, Table 1) or cellulolytic enzymes (NB_{16}, Table 1) improved DMI, ADG and feed conversion efficiency, with yeast culture better than cellulolytic enzymes [14]. In grazing sheep fed LB containing fenbendazole, the egg count of worms in feces decreased by 98% on D 14 when compared with D 0 [15]. Junkuszew et al. [16] reported that both drenching de-wormer (containing albendazole) and feeding LB (containing essential oils from 10 plant species with anti-parasitic properties) effectively reduced coccidia in lambs. In Laos, where the administration of anthelmintics to buffalo is difficult due to a lack of restraint facilities, adding fenbendazole (NB_{17}, Table 1) or triclabendazole to LB provided anthelmintic control of *Toxocara vitulorum* and *Fasciola gigantica*, which is particularly important for the smallholder [64,96]. It is worth noting, however, that in open pastures grazed by wildlife, LBs can transmit disease between grazing livestock and wildlife. Bovine tuberculosis is caused by *Mycobacterium bovis*, a bacterium belonging to the *Mycobacterium tuberculosis* complex (MTC). This disease can spread among livestock, humans and wildlife [97]. According to Kaneene et al. [17], MB inoculated with *Mycobacterium bovis* can survive up to 78 h in winter or in the shade. Although LB is less attractive to wildlife than domestic animals, the potential for interspecific transmission of MTC or other pathogens cannot be discarded [18]. Adjusting the feeding time and location of LB can reduce the number of wildlife visits to LB and reduce the risk of disease transmission [18].

7.4. Lick Blocks Can Modulate the Distribution of Grazing Livestock

When ruminants graze pastures, especially during the period of low-quality forage, they usually select areas close to a water source and gentle terrain. They tend to avoid areas far from a water source, rugged terrain and high elevations [98–100]. This results in the concentration of animals in certain areas, leading to localized over-grazing. The strategic placing of NBs can influence cattle grazing patterns [19]. Bailey et al. [20] compared the effects of strategically placed MB (salt content 99.9%) and NB and only MB (salt content 99.9%) on grazing distribution and diurnal behavior patterns of cows grazing foothill rangeland in northern Montana during autumn. When NB was available, cows used higher elevations and grazed further from water points than when only salt was provided. NB attracts cattle to under-utilized pasture, improves grazing uniformity and reduces grazing pressure in priority feeding areas.

8. Summary and Prospects

Dietary supplementation is an important aspect of livestock husbandry, as inadequate nutrients, minerals, vitamins and energy can reduce productivity. At present, there is a shortage of dietary resources, the price of feed ingredients is high, and the supply of animal products is in demand. The global COVID-19 epidemic has led to a more prominent shortage problem of forage. Supplementary LB has proven to be a low-cost, efficient and easy method to improve the feeding of ruminants and has broad development and application prospects. However, LB production should set standards and a quality evaluation system, which would lead to appropriate hardness and waterproofness. The aspects of LB that need research and improvement in the future include:

1. Introduction of a consistent naming system, production standards and quality evaluation system for LB;
2. Testing cost-effective alternative local feed resources to reduce production costs;
3. Improvement of the use of agro-industrial by-products to replace concentrates and reduce feed costs;
4. Use of LB as a carrier for novel additives to increase the application effect;
5. Use of LB in non-ruminant feeds to further expand the application scope.

Table 3. Effects of lick blocks on production and reproductive performances of ruminants.

Animal	LB	Intake (g/d)	Productive Performance					Reproductive Performance	Other	Ref.
			ADG (g/d) [1]	Increase (%) [2]	Milk Yield (kg/d) [3]	Increase (%) [4]	Other			
1-yr-old yak	NB_3	250.0	1.2 [5]	102.5 [6]	-	-	-	-	-	[2]
2-yr-old yak		250.0	8.3 [5]	85.6 [6]	-	-	-	-	-	
Yak cows		500.0	7.8 [5]	95.1 [6]	0.2	16.3	Improve cheese and butter production	Improve pregnancy and birth weight	-	
Yak calves	MB	16.0	50.0	60.8	-	-	-	-	Increase content of minerals in serum; improve rumen fermentation	[90]
Young yaks	MB	100.0	91.8	30.4	-	-	-	-	-	[91]
Yak calves		100.0	80.5	18.3	ns [7]	ns	-	-	-	
Adult yaks		100.0		ns	ns	ns	-	-	-	
Tibetan sheep	NB	21.0	43.5	97.8	-	-	Improve nutrient intake and digestibility; increase content of growth hormone in serum	Increase content of reproductive hormone in serum; increase weight of uterus-ovary; promote follicular development	Improve activity of digestive enzymes in rumen fluid; increase number of nutrient degrading bacteria; improve rumen fermentation; promote morphological development of rumen and small intestine and absorption capacity of nutrients	[3]
Tibetan sheep	MB	13.1	-	-	-	-	-	-	Increase content of minerals in serum; enhance antioxidant capacity and immune capacity	[101]
Beef cattle	NB_4	-	280.0	43.8	-	-	Increase body size index	-	Increase content of minerals in serum and hair	[8]
Beef cattle	NB	-	140.0	11.2			Improve DMI	-	-	[93]
	MB	-	100.0	8.0	-	-	-	-	-	
Dairy cows	NB_5	-	ns	ns	1.5	11.9	Improve milk fat content	Shorten calving interval	-	[7]

Table 3. *Cont.*

Animal	LB	Intake (g/d)	Productive Performance					Reproductive Performance	Other	Ref.
			ADG (g/d) [1]	Increase (%) [2]	Milk Yield (kg/d) [3]	Increase (%) [4]	Other			
Dairy cows	MB	44.3	-	-	-	-	-	Improve frozen semen yield and quality	-	[102]
Lactating dairy cows	MB	41.8	-	-	ns	ns	Improve milk quality; decrease average number of somatic cells in milk	-	Decrease the incidence of mastitis; increase centrations of vitamin E and selenium in milk and serum	[47]
Pregnant dairy cows		47.3	-	-	-	-	-	Increase level of reproductive hormones in postpartum cow serum; shorten interval from delivery to first estrus	Decrease incidence of postpartum diseases in cows and increase the contents of vitamin E and selenium in serum	
Buffalo	NB_6	230.0	142.9	100.0	2.2	27.0	Improve DMI; Improve condition score			[11]
2-yr-old ewes	NB	31.1	45.3	859.0	-	-	-	-	-	[92]
Pregnant ewes		43.2	-	-	-	-	-	Improve birth weight of lamb	-	
Young ewes	MB_2	12.3	4.5	282.5	-	-	-	-	-	[66]
Adult ewes		14.6	-	-	-	-	-	Improve birth weight, survival rate, number of weaned lambs and lambing rate of ewes	-	
Sheep	MB	-	31.9	32.8	-	-	-	-	Improve carcass and meat quality;	[10]
Sheep	MB_1	33.0	37.0	18.6	-	-	Decrease feed to meat ratio; increase water consumption	-	enhance antioxidant capacity; increase content of minerals in serum	[65]

Table 3. *Cont.*

Animal	LB	Intake (g/d)	Productive Performance					Reproductive Performance	Other	Ref.
			ADG (g/d) [1]	Increase (%) [2]	Milk Yield (kg/d) [3]	Increase (%) [4]	Other			
Goats	NB_7	10.4–14.5	10.5–21.8	22.3–46.5	-	-	Improve DMI and digestibility	-	Improve wool condition	[4]
Goats	NB_8	16.0	17.5	31.6	-	-	Improve wool production	-	Improve wool condition	[62]
Dairy goats	NB_9	-	16.0–25.2	25.2–39.7	0.2	12.8–18.4	Increase body size index	-	increase number of blood cells; increase content of minerals in whole blood	[55]
Goats	MB	-	16.7	70.9	-	-	Decrease feed to meat ratio	Improve semen yield and quality	-	[9]
Dairy goats	NB_{10}	83.9	ns [7]	ns	ns	ns	No difference in nutrient intake and apparent digestibility, nitrogen and energy utilization and milk composition	-	No effect on rumen fermentation; Feeding cost reduced by 10.9%	[13]
Dairy goats	NB_{11}	66.7	2.7 [8]	245.5 [9]	ns	ns	Decrease intake of concentrate; no difference in nutrient intake and milk composition, except EE	-	-	[12]

[1,3] ADG or Milk yield = Trial − control; [2,4] Increase = (Trial − control)/control; [5,6] total weight gain date; [7] Non-significant; [8,9] Decrease and decrease range of ADG, respectively, compared with control group.

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