INTRODUCTION

Alfalfa (*Medicago sativa*) is a herbaceous plant from the legume family. It is prized as fodder for ruminants owing to its excellent nutritional properties and its high degree of palatability.

At present, alfalfa is used in total mixed rations for dairy cattle in different forms (hay, silage, dehydrated), chopped to a particle size appropriate for proper rumen function. Dehydrated alfalfa has gained popularity due to its advantages. By reducing dependence on weather conditions it allows harvests to be planned in a more rational way. They can be performed according to the stages when the nutritional value of the fodder is at its highest. Moreover, through working with fodder with a greater moisture level, losses are also reduced during fodder collection. At the same time, the artificial drying process allows greater and more homogeneous drying to be achieved, which reduces the risks of microbial contamination during fodder storage and demands less time to be spent in the unifeed cart to reduce particle size.

This article discusses the nutritional value of alfalfa and its use as an alternative to soya. It also notes the specific advantages that dehydrated alfalfa offers over hay.
The energy, fibre and protein content of alfalfa varies based on different factors. The phenological state of the plant at the time of harvest is the most influential factor here. As Figure 1 shows, the highest protein content is obtained when the plant is harvested in the early stages before flowering. As the plant ripens, its fibre content increases and it becomes less digestible and the ratio of leaves to stalks also decreases (0.55, 0.42 and 0.37, respectively for the initiation stages of flower buds, advanced buds and early flowering) (Yari et al., 2012).

Alfalfa is a good source of soluble fibre, and can account for approximately 10 to 20% of dry matter. As with crude protein content, the ratio of soluble fibre decreases as the alfalfa plant matures, becoming lower as the proportion of leaves decreases and that of stems increases. The pectin content of alfalfa is of great functional importance because pectins are highly digestible and
do not lower ruminal pH as they ferment, thereby reducing problems related to ruminal acidosis in animals consuming diets with high levels concentrate.

Due to the significant effect of the phenological state, it is very important to harvest at the most appropriate time. This is only possible when dependence on weather conditions is reduced. For this reason, better fodder is often produced when alfalfa is artificially dehydrated than when a haymaking process is used.

Regardless of the effect of the phenological state, when comparing fodders that are commonly used for dairy cattle, such as Timothy grass (*Phleum pratense*), orchard grass (*Dactylis glomerata*), Bermuda grass (*Cynodon dactylon*), red clover (*Trifolium pratense*), bird's-foot trefoil (*Lotus corniculatus*) and alfalfa (*Medicago sativa*), a big difference in chemical composition between grass (*Phleum pratense, Dactylis glomerata* and *Cynodon dactylon*) and legumes (*Trifolium pratense, Lotus corniculatus* and *Medicago sativa*) can be seen, as Figure 2 shows. Usually, legumes have a higher protein content and a lower neutral detergent fibre content, although this tends to be more lignified. Legumes have a higher percentage of protein and soluble fibre and a lower percentage of insoluble fibre, although the latter is usually more lignified and less digestible.

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**FIGURE 2**

Forage legumes have a higher content of protein and less fiber than grass forages used for dairy cows. Source: by the authors, based on data from www.feedipedia.org (INRA, CIRAD, FAO, AFZ).
Among legumes, clover hay, and especially red clover hay, has a nutritional value similar to alfalfa fodder. But since it dries more slowly, it is not usually used for haymaking. As a result, it is a fodder that is practically not offered commercially. Furthermore, different studies have indicated a reduction in the protein content of the milk comes about when alfalfa is replaced with clover in dairy cattle's feed.

A similar effect has been observed in Chinese Holstein cows when comparing feed using wild ryegrass hay and alfalfa hay as the sole source of fodder (Zhu et al., 2013). The authors of that study found that this effect was related to a greater intake of digestible protein in the intestine, primarily as a result of a higher synthesis of microbial protein in the rumen. It should be noted that this increased synthesis was the result of an increased availability of energy for the microorganisms and not of differences in protein degradability, and it resulted in a lower elimination of N in excretion. This aspect is of great importance from an environmental-impact perspective, since it would lead to a reduction in emissions of nitrous oxide (a greenhouse gas).

At the same time, the composition of the protein in alfalfa is very balanced, and this can also be decisive in the efficiency with which the protein provided by alfalfa is used being higher than that of other foods. Figure 3 shows the proportion of the main amino acids in cow's milk and alfalfa. As can be seen, with the exception of arginine the amino acid profile, are very similar.
It is important to mention that the protein in alfalfa has a relatively high degradability, and usually less than 60% of it reaches the small intestine without degradation. It has been suggested that heat treatment during artificial dehydration of alfalfa can cause reactions that reduce the degradability of the protein in alfalfa in the rumen. During the process of dehydration, a series of complex nonenzymatic chemical reactions mediated by the heat can come about. It involves the existing amino acids and sugars and is known as the Maillard reaction. These reactions insolubilize part of the proteins in the Maillard complexes, which possess similar chemical properties to lignin. These may reduce protein digestibility. However, if heat treatment is of limited duration, complexes that are stable at pH values of between 6 and 7 values but that separate with acidic pHs (typical of the stomach) and alkaline ones (typical of the intestine) are formed. As a result, the complexes would be nondegradable in the rumen, but they would subsequently be digestible in the later sections of the digestive tract. In fact, different authors have observed an increase in the content of nondegradable protein in the rumen, increasing the amount of protein from alfalfa that reaches the intestine (Broderick et al., 1993; Price et al., 1988; Polan et al., 1998). However, if the heat treatment is inadequate, indigestible complexes could appear.
Moreover, in recent years, many consumers have become more aware of the incidence of diseases related to fat consumption and the concepts of omega 3 and 6 and conjugated linoleic acid (CLA) are now well known. Although alfalfa has a low fat content compared with other foods (e.g. legume seeds), it has a relatively high proportion of linolenic acid (40% of total fatty acids), which is a precursor of CLA.

**FIGURE 4**
Heat treatment of alfalfa can reduce protein degradability, increasing feed protein reaching small intestine.
Alfalfa has a more balanced mineral profile than other foods, with a high calcium content. Legumes usually have a higher calcium content than grasses (Figure 6).
The high calcium content in alfalfa endows it with added value for use in rations for high production dairy cattle, given their high needs for this mineral. However, due to its calcium content and buffering capacity, the use of alfalfa should be restricted in cows in the dry period since it could limit postpartum calcium mobilisation.

EFFECT OF THE INCLUSION OF ALFALFA ON INGESTION, DIGESTIBILITY AND MILK PRODUCTION

Alfalfa is a fodder with a high protein content. This characteristic, coupled with its high digestibility, along with soluble fiber, calcium content and buffer capacity, allows it, unlike other fodders, to be included in dairy cattle feed in high proportions. As a result, numerous studies have evaluated the effect of the partial replacement of fodders and protein supplements such as soybean cake with alfalfa in the diet of high-yield dairy cattle.

Based on the studies carried out, it can be concluded that the effect of including dehydrated alfalfa depends on the level of inclusion and the feed into which it is incorporated. No effects have been encountered and no negative or positive effects have been observed in relation to intake, digestibility and the production and composition of the milk.
For example, Thénard et al. (2002) found that the use of 3 kg of dehydrated alfalfa instead of silage grass and corn to feed cows during the first 15 weeks of lactation allowed a reduction in the amount of soy flour without affecting the energy and protein balance. Milk production did not change, but its composition did. When alfalfa was included, protein content increased, while fat content remained the same. However, these authors concluded that the added value of the inclusion of alfalfa resulted primarily from an improvement in ruminal conditions and a reduction in acidosis, which also translated into a lower incidence of mastitis.

Other authors (Peyraud and Delaby, 1994) have observed that the inclusion of 2.5 kg of dehydrated alfalfa instead of alfalfa hay from concentrate increased milk production (30.4 kg to 31 kg), although it reduced the fat content of the milk (4.1% to 3.9%), albeit not in absolute values (1.23 kg/day vs. 1.21 kg/day). When the alfalfa content of the feed was doubled (5 kg), milk production did not increase, but the percentage of protein and fat slightly decreased (3.07% to 3.01% and 4.1% to 4.0% respectively), with the absolute values being similar (kg/day).

Upon including 25% dehydrated alfalfa in the dairy cattle feed as a replacement for the same quantity of concentrated form, Christensen & Cochran (1983) did not observe differences in ingestion or parameters indicative of ruminal fermentation (pH, ammonia, volatile fatty acids or hydrogenase activity). However, with an amount included at a similar percentage level (22.5%) as a substitute for part of the concentrate, Kirkpatrick et al. (1984) observed a reduction in the digestibility of dry matter, with ingestion not being affected. Similar results were observed in a more recent work, in which 30% protein supplementation (comprising 15% soybean cake) was replaced with dehydrated alfalfa in dairy cow feed (Doreau et al., 2014). It should be noted that in this research a reduction in milk production was also observed.

Price et al. (1988) studied the inclusion of dehydrated alfalfa in the diets of dairy cows in two different tests. For this purpose, they used silage corn as fodder and a different concentrate, one based on corn and soybean cake, and the other using dehydrated alfalfa and a different proportion of corn. In neither case differences were observed in the digestibility or ingestion of the dry matter. When dehydrated alfalfa was included in the diet, the percentage of degraded protein in the rumen decreased, as indicated by the lower values of ammonia in the rumen, thus increasing the amount of amino acids that reached the intestine. In this study, a reduction in milk production and protein content was observed, being increased the milk fat content. These authors also found a higher acetic/propionic rate, suggesting a less acidogenic ruminal fermentation. It should be borne in mind that alfalfa has a relatively high proportion of soluble fibre and a higher buffer capacity than that of soybean meal and other forage crops.
Dehydrated alfalfa can be also supplied as pellets. In this regard, Christensen & Cochran (1983) observed that lactation is not affected by the replacement of up to 6 kg of concentrate with dehydrated alfalfa in pellet form.

It can be concluded, therefore, that the inclusion of dehydrated alfalfa in appropriate proportions in dairy cattle's feed can reduce the use of soybean meal and improve ruminal fermentation, without affecting milk production. Mauriès (1991) indicates that dehydrated alfalfa can be used in amounts of 4 kg to 8 kg per day without any negative effect on the production of milk, though he points out that factors such as the protein content of alfalfa, ripeness level, level of concentrate or the nature of the diet will determine the effect on ingestion, digestibility and production.
### Effects of Substitution of Concentrate by Dehydrated Alfalfa

<table>
<thead>
<tr>
<th>Reference</th>
<th>Animal</th>
<th>Inclusion level</th>
<th>Feed intake</th>
<th>Digestibility</th>
<th>Protein contribution to intestine</th>
<th>Milk production</th>
<th>Milk protein content</th>
<th>Milk fat content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price et al. (1988)</td>
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<td>25.3%</td>
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<td>-</td>
<td>-</td>
<td>+</td>
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<td>3-6 kg of concentrate</td>
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<td>No data</td>
<td>=</td>
<td>-</td>
<td>=</td>
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<tr>
<td>Kirkpatrick et al. (1984)</td>
<td>Dairy cows</td>
<td>15-45% of concentrate</td>
<td>=</td>
<td>DDM = DCP =</td>
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<td>+</td>
<td>DDM - DCP -</td>
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<td>Bocquier et al. (2000)</td>
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<td>Loerch et al. (1983)</td>
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<td>DDM = DCP -</td>
<td>+</td>
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<td>No data</td>
<td>No data</td>
</tr>
</tbody>
</table>

**Figure 7**

The inclusion of dehydrated alfalfa in dairy cattle reduces concentrate without being diminished production or other productive parameters.
ADDITIONAL ADVANTAGES OF DEHYDRATED ALFALFA OVER HAY

The use of dehydrated alfalfa has some advantages over alfalfa hay:

- It requires less time to be chopped in the unifeed cart, which saves on costs (mainly fuel) and time in the preparation of the feed.
- It has a lower moisture content, which means on the one hand a lower cost of transportation per nutrient unit and on the other a reduction in the risk of deterioration during storage.
- Appropriate heat treatment could reduce the degradability of protein relative to hay, without affecting the digestibility. If feed is properly formulated, this difference in the degradability could allow a more efficient use of protein, reducing the excretion of N into the environment and the emission of greenhouse gases from droppings.
- It improves the hygienic and phytosanitary quality. On the one hand, heat treatment coupled with improved drying conditions reduces the risk of deterioration of the fodder through fungal growth and Mycotoxin contamination. Mycotoxins are secondary compounds produced by moulds. They may occur before harvesting or during improper storage conditions. Animal health can be affected by consumption of them, and they can reduce productivity performance. They can also reach the food chain, since they can be transferred to milk.

Heat treatment during the process of dehydration helps to eliminate insects that may be present in feed. Seeds from other plants that are considered weeds can be transferred into fodder. These seeds may remain dormant for long periods of time until environmental conditions are favourable for the onset of germination. In the case of fodder, storage time does not negatively affect this type of seed, and when the animal eats them, they may pass through the digestive tract of the animal and be expelled undigested with the faeces while still having their capacity to germinate. They may then spread in an area different from their place of production, causing the kind of environmental damage that the introduction of potentially invasive non-native species can give rise to. Although dehydration is not a method specifically designed for controlling pests or weed populations, in an indirect way, the alfalfa dehydration process provides an extra benefit to such controls. The temperature that the fodder reaches in the dehydration drum may help to destroy some micro-organisms, arthropods and seeds, etc., increasing the hygienic quality of alfalfa without damaging its nutritional quality.
CONTROL MEASURES FOR THE PRODUCTION OF DEHYDRATED ALFALFA

International legislation relating to the import/export of long-life fodder for cattle is very restrictive. It is essential to use different control methods, which are strictly applied for fodder to international trade.

In this regard, trade agreements set out the requirements for the cultivation of alfalfa itself, the location of the dehydration facilities, the technical features of the dehydration procedure, and storage and transport. Table 2 outlines the conditions laid down in the agreement between the Spanish Government and People's Republic of China on sanitary requirements for exporting alfalfa.
### FIGURE 8

General aspects of the agreement on sanitary requirements for alfalfa (Medicago sativa) exportation between the Spanish Ministry of Agriculture, Food and Environment (MAGRAMA) and the General Administration of the Quality Supervision and Inspection Guarantine of the People’s Republic of China (AQSIQ) of 2014.
BIBLIOGRAPHY


