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(54) Title: IMPROVED ADDITIVE FOR LIVESTOCK FEEDS

(57) Abrégé/Abstract:
Improved particulate feed additives and methods are provided for enhancing feed utilization efficiency in a ruminant animal by adding to the feed of the animals a particulate feed additive comprising a particulate carrier substrate coated with a sufficient amount of a nonionic surfactant to enhance the utilization of the feed by the animal and a sufficient amount of an antioxidant agent to substantially enhance the shelf life of the feed additive. The methods and compositions result in enhanced weight gain and/or milk production by the animal.

ADDITIVE FOR LIVESTOCK FEEDS

Abstract of the Disclosure

Improved particulate feed additives and methods are provided for enhancing feed utilization efficiency in a ruminant animal by adding to the feed of the animals a particulate feed additive comprising a particulate carrier substrate coated with a sufficient amount of a nonionic surfactant to enhance the utilization of the feed by the animal and a sufficient amount of an antioxidant agent to substantially enhance the shelf life of the feed additive. The methods and compositions result in enhanced weight gain and/or milk production by the animal.

IMPROVED ADDITIVE FOR LIVESTOCK FEEDS

Field of the Invention

The present invention relates generally to ruminant feed compositions containing nonionic surfactants, either alone or in combination with digestion enhancing agents, and to methods for enhancing feedstock utilization efficiency in ruminant livestock. More particularly, this invention relates to the stabilization of nonionic surfactants in particulate ruminant feed additives.

Background of the Invention

Anaerobic fermentation occurs during ruminant digestion, during which proteins and carbohydrates are degraded. It is desirable in ruminant digestion to be able to control protease and carbohydrase activity to optimize the digestive process.

Since feed is a major cost in ruminant production, enhancing digestive efficiency remains a driving objective in the industry. Although forages remain the major feed source, it is widely believed that the efficiency of feed utilization by ruminants has remained relatively unchanged during the last two decades. New innovations that enhance the digestive efficiency provide a compromise to emerging environmental concerns regarding ground water pollution in most dairying areas. Nevertheless, an in depth understanding of the roles of feed processing and bacterial digestion are required to fully manipulate the digestive processes of the rumen. Cheng et al. ("Microbial ecology and physiology of feed degradation within the rumen," in *Physiological aspects of digestion and metabolism in ruminants: Proceedings of the seventh international symposium on ruminant physiology*, Tsuda, Ed., 1991) has identified the following three general factors as influencing microbial digestion of feeds: (a) plant structures that regulate bacterial access to nutrients; (b) microbial factors that control adhesion and the development of digestive microbial consortia; and (c) complexes of oriented hydrolytic enzymes of the adherent microorganisms. Feed processing practices, e.g., grinding, normally attempt to increase enzyme-substrate interaction by the exposition of susceptible substrate binding sites.

The manipulation of digestion within the rumen in order to increase the efficiency of feed utilization has been achieved through the use of exogenous enzymes (Feng et al., "Effect of enzyme additives on *in situ* and *in vitro* degradation of mature cool-season grass forage," *J. Anim. Sci.* **70 (Suppl. 1)**:309 (1996)), and such compounds as ionophore antibiotics, methane production inhibitors, inhibitors of proteolysis or deamination, and buffers (Jouany, "Methods of manipulating the microbial metabolism in the rumen," *Ann. Zootech.* **43**:49-62 (1994)). The increased digestive efficiency realized through the use of these compounds is the result of major shifts in microbial fermentation pathways. For example, the selective use of antibiotics can alter the rumen microbial population and ultimately influence the end products of digestion. Antibiotics are, however, used only in meat producing animals because of the risk of antibiotic transfer to milk. Production responses of animals fed exogenous enzymes have been inconsistent. Exogenous enzymes have been shown to increase (Beauchemin et al., "Fibrolytic enzymes increase fiber digestibility and growth rate of steers fed dry forages," *Can. J. Anim. Sci.* **75**:641-644 (1995)), to not affect (Perry et al., "Effects of supplemental enzymes on nitrogen balance, digestibility of energy and nutrients and on growth and feed efficiency of cattle," *J. Anim. Sci.* **25**:760-764 (1966)), and even to decrease (Svozil et al., "Application of a cellulolytic preparation in nutrition of lambs" *Sbor. Ved. Praci. VUVZ Prhrelice* **22**:69-78 (1989)) the growth performance of ruminants fed forage or concentrate-based diets. The inconsistency is partly due to the numerous enzyme preparations available, application methods, and their interaction with different types of diets.

Long-chain fatty acids and the halogen homologues of methane have been found to reduce methane production in the rumen (Van Nevel et al., "Manipulation of rumen fermentation," In: *The Rumen Microbial Ecosystem.*, Ed. P.N.Hobson. Elsevier Applied Science, London, pp. 387 et seq. (1988)). The reduction in methane production is usually associated with a decrease in deamination of amino acids, particularly, branched-chain amino acids and an increase in propionic acid production. The main limitation with the use of these additives is that rumen microbes are able to adapt and degrade them after about one month of treatment. Another disadvantage is that the beneficial effect appears to be consistent only in forage-based diets that favor methane production.

Buffers are mainly used under conditions where the feeding of high levels of grains can induce an active fermentation and cause excess production of acids within the rumen. They act by regulating and maintaining the pH at levels at which the cellulolytic microorganisms can be of maximum effectiveness (pH = 6-7). The digestion of starch and proteins is generally decreased when buffers are fed, however, the effect on the digestion of cell wall carbohydrates is inconsistent (Jouany, "Methods of manipulating the microbial metabolism in the rumen," *Ann. Zootech.* **43**:49-62 (1994)).

Surfactants have been used in the food processing industry as emulsifiers and extenders (Griffin et al., "Surface Active Agents," in *Handbook of Food Additives*. 2nd Ed., T.E. Furia, Ed., CRC Press, New York, New York, p 397 et seq. (1972)) and also as cleaning agents. The most well known physicochemical property of surfactants is their interfacial activity when placed in solution. Their ability to align at the interfaces is a reflection of their tendency to assume the most energetically stable orientation. One type of nonionic surfactant, the polyoxyethylene sorbitan esters, is synthesized by the addition, via polymerization, of ethylene oxide to sorbitan fatty acid esters. These nonionic hydrophilic emulsifiers are very effective antistaling agents and are therefore used in a variety of bakery products. They are widely known as polysorbates. The effects of the polysorbate Tween™80 on the hydrolysis of newspaper was investigated by Castanon et al., "Effects of the surfactant Tween™80 on enzymatic hydrolysis of newspaper," *Biotechnol. & Bioeng.* 23:1365 (1981). However, the effects of nonionic surfactants on ruminant digestion have not heretofore been contemplated.

More recently, Shelford et al. U.S. Patent No. 6,221,381 issued April 24, 2001 discloses that when nonionic surfactants are admixed in ruminant feedstuffs at a concentration of from about 0.01 to 1% (w/w) and the feedstuffs are fed to ruminants, significantly higher productivity can be expected from these animals. Higher productivity may be characterized by higher milk yield, increased rate of weight gain, higher efficiency in converting feed into body tissues or milk, and/or a reduction in manure production. This patent further discloses that when nonionic surfactants at a concentration of from about 0.01 to 1% (w/w) are combined with digestive enzymes, such as glycanases, and admixed with ruminant feeds, ruminant animals consuming said feed have higher feed conversion efficiencies and productivity.

In one embodiment of U.S. Patent No. 6,221,381, the nonionic surfactant is coated on a carrier such as celite, diatomaceous earth, or silica and admixed with the feed before feeding the feed to the animal. The surfactant coats the surface of the carrier to enhance attachment of enzymes and or bacteria once the animal consumes the feed material.

Although the methods and compositions of U.S. Patent No. 6,221,381 have been found to result in substantial enhancements in milk production in dairy herds and substantial enhancements in weight gain in feedlot cattle, it has now been discovered that liquid nonionic surfactant materials containing unsaturated fatty acid chains, when coated onto a particulate carrier, are subject to rapid surfactant degradation and rancidity development. The present invention provides improved compositions and methods that utilize stabilized nonionic surfactants to substantially extend the shelf life of surfactant coated, particulate feed enhancing compositions. The compositions and methods described in this invention optimize the digestive process in ruminant animals, enhance productivity of ruminant animals, reduce waste production and ultimately improve profitability.

Summary of the Invention

The present invention provides new and surprising methods and compositions for enhancing feed utilization efficiency in ruminant animals, such as cattle, sheep, goats, deer, bison, water buffalo and camels. In particular, it has now been discovered that when antioxidant materials are added to the nonionic surfactants of particulate feed additives of the type disclosed in U.S. Patent No. 6,221,381 an improved feed additive product results that exhibits a substantially extended shelf life. The improved particulate feed additive product may then be admixed in ruminant feedstuffs at a concentration of from about 0.01 to 1% (w/w) based on the ratio of the weight of the surfactant in the feed additive to the weight of the feedstuffs fed to ruminants, resulting in significantly higher productivity from these animals. Higher productivity may be characterized by higher milk yield, increased rate of weight gain, higher efficiency in converting feed into body tissues or milk, and/or a reduction in manure production. It has also been discovered that when the stabilized nonionic surfactants at a concentration of from about 0.01 to 1% (w/w) based on the ratio of the weight of the surfactant in the feed additive to the weight of the feedstuffs fed to ruminants are combined with digestive enzymes, such as glycanases, and admixed with ruminant feeds, ruminant animals consuming said feed have higher feed conversion efficiencies and productivity.

In other aspects, the present invention provides compositions and methods that modify fermentation within the rumen towards more propionic acid production at the expense of acetic acid. Less heat is produced during the metabolism of propionic acid in the animal compared to that produced during the metabolism of acetic acid. Therefore the methods and compositions of the invention may be used to mitigate the effect of heat stress in ruminant animals.

In one preferred embodiment of the present invention, a nonionic surfactant is mixed with a suitable antioxidant agent and then coated onto a particulate carrier such as celite, diatomaceous earth, or silica to form a particulate feed additive material. The feed additive may then be admixed with animal feed before feeding the feed to an animal. Mixing of the coated particles with the feed ensures even distribution of the surfactant in the entire feed material, to enhance attachment of enzymes and or bacteria once the animal consumes the feed material, while inclusion of an antioxidant in the coating substantially enhances the shelf life of the particulate feed additive product.

Detailed Description of the Preferred Embodiment

According to one aspect of the present invention, methods and compositions are provided for enhancing feed utilization efficiency in ruminant animals, comprising adding to the feed of the animals a sufficient amount of a nonionic surfactant coated particulate feed additive to enhance the utilization of the feed by the animal. In this aspect of the invention, the particulate feed additive coating comprises, in addition to the surfactant, a sufficient amount of an antioxidant material to substantially increase the shelf life of the particulate feed additive.

The term "feed efficiency" or "feed utilization" or "feed conversion" as used herein means the amount of feed needed to obtain a given amount of weight gain or milk production. In particular, feed efficiency or utilization expresses the efficiency by which an animal converts feed into weight gain or milk production. Feed efficiency is expressed as the ratio of weight of feed to weight gain (or milk production).

Although the terms "feed efficiency" and "weight gain" are often used together, there is a significant difference between the two as can be seen by the above definitions. Specifically, the determination of feed efficiency depends upon a given weight gain or milk production whereas the determination of weight gain or absolute milk production does not depend upon a given feed efficiency. The differences are especially significant to an animal producer or dairy farmer. In particular, weight gain or milk production can be achieved with little, no or even negative change in feed efficiency. Thus, for the animal producer, merely obtaining increases in weight gain or milk production may not necessarily be a more cost effective method for growth of the animal. While a producer looks at numerous factors in determining the cost of production, feed utilization efficiency is probably the most important and has the most impact on cost per pound of meat produced.

Thus, in one aspect of the invention, new particulate feed additives and methods are provided for enhancing weight gain in a ruminant animal for a given amount of animal feed, comprising adding to the feed a sufficient amount of a particulate feed additive to enhance the weight gain by the animal, wherein the particulate feed additive comprises a particulate substrate coated with a nonionic surfactant and an antioxidant agent. In yet other aspects of the invention, methods and compositions are provided for enhancing milk production by a ruminant animal, comprising adding to the feed of the animal a sufficient amount of a particulate feed additive to enhance milk production by the animal, wherein the particulate feed additive comprises a particulate substrate coated with a nonionic surfactant and an antioxidant agent. In still other aspects of the invention, methods and compositions are provided for reducing the adverse effects of heat stress in a ruminant animal, comprising adding to the feed of the animal a sufficient amount of a nonionic surfactant to enhance feed utilization efficiency, enhance weight gain and/or enhance milk production by the animal.

As used herein, the term "ruminant" means an even-toed hoofed animal which has a complex 3- or 4-chambered stomach, and which is characterized by chewing again what it has already swallowed. Some examples of ruminants include cattle, sheep, goats, deer, bison, water buffalo and camels.

As used herein, "surfactant(s)" include surface active agents that are organic or organic-metal molecules that exhibit polar and solubility behavior that result in the phenomenon known as surface activity. The most commonly recognized phenomenon in this respect is the reduction of the boundary between two immiscible fluids. Surfactants include surface active agents, which act as emulsifiers, wetting agents, solubilizers, detergents, suspending agents, crystallization modifiers (both aqueous and non aqueous), complexing agents and in other ways. The surfactants most useful in the practice of the present invention are the nonionic surfactants, including, without limitation, polyoxyethylenesorbitan monooleate (Tween™60), polyoxyethylenesorbitan trioleate (Tween™80), polyoxyethylenesorbitan monostearate, alkyltrimethylammonium bromides, dodecyltrimethylammonium bromide, hexadecyltrimethylammonium bromide, mixed alkyltrimethylammonium bromide, tetradecyltrimethylammonium bromide, benzalkonium chloride, benzethonium chloride, benzyldimethyldodecylammonium bromide, benzyldimethylhexadecylammonium bromide, benzyltrimethylammonium chloride, benzyltrimethylammonium methoxide, cetylpyridinium bromide, cetylpyridinium chloride, cetyltributylphosphonium bromide, cetyltrimethylammonium bromide, decamethonium bromide, dimethyldioctadecylammonium bromide, methylbenzethonium chloride, methyl mixed trialkyl ammonium chloride, methyltrioctylammonium chloride, n,n',mb'-polyethylene(10)-n-tallow-1,3-diamino-propane and 4-picoline dodecyl sulfate. In the most preferred form of the invention, the nonionic surfactant is selected from the group consisting of polyoxyethylenesorbitan monooleate (Tween™60) and polyoxyethylenesorbitan trioleate (Tween™80).

For purposes of the present invention, the term "antioxidant agent" includes antioxidant compounds that are compatible with and suitable for use in animal feeds. Useful antioxidant agents include, for example, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), ethoxyquin, propyl gallate, tertiary butyl hydroquinone (TBHQ), tocopherols and the like. The antioxidant agents will generally be employed in the particulate feed additive coatings of the invention in amounts effective to substantially increase the shelf life of the feed additives, such as by substantially reducing the rate of rancidity conversion in the surfactant materials of the invention. Useful amounts of the antioxidant agents will generally range from about 50 to about 5000 ppm, more preferably from about 100 to about 2000 ppm, and most preferably from about 200 to about 1000 ppm, based on the surfactant solution employed to coat the particulate feed additive material.

The surfactant and antioxidant agents of the invention are with mixed a particulate carrier substrate so that a coating is formed on the carrier substrate comprising about 10% to about 70% (wt/wt), more preferably about 20% to about 65% (wt/wt) and most preferably about 40% to about 60% (wt/wt) of surfactant based on the combined weight of the particulate carrier material and coating. A particularly useful amount of surfactant/antioxidant coating material is about 50% (wt/wt) based on the combined weight of the coated product. Particulate carrier materials useful as a substrate for the surfactant/antioxidant coating of the invention include substantially inert particulate carrier materials that are suitable for feed additive applications. Suitable particulate carrier materials include, but are not limited to celite, diatomaceous earth, and silica. Specific, non-limiting examples of useful carriers include, for example, celite (Fisher Scientific Co., New Jersey, USA), diatomaceous earth (Sigma Chemical Co. St. Louis, MO) and LuctaCarrier™ silica (Lucta, S.A., Barcelona, Spain).

The coated particulate feed additive of the invention formed as described above may be added to animal feed in an amount sufficient to enhance feed utilization efficiency in the animals. For purposes of the present invention, effective amounts of the feed additive, when mixed with the animal feed, will typically be obtained when the amount of the nonionic surfactants and their derivatives coated on the particulate substrate carrier are from about 0.01 to 1% (w/w) of the dry weight of the feed, preferably from 0.01 to 0.5% (w/w) of the dry weight of the feed, and most preferably from 0.01 to 0.3% (w/w) of the dry weight of the feed.

Feedstuff or feed useful in the practice of the present invention includes forages and grain feeds, such as grass and legume forages, crop residues, cereal grains, legume by-products and other agricultural by-products. In situations where the resulting feed is to be processed or preserved, the feed may be treated with the surfactant and/or enzyme before processing or preservation. Processing may include drying, ensiling, chopping, pelleting, cubing or baling in the case of forages, and in the case of grains and legume seeds by rolling, tempering, grinding, cracking, popping, extruding, pelleting, cubing, micronizing, roasting, flaking, cooking and or exploding.

As used herein, "forages" include the cut aerial portion of a plant material, both monocotyledonous and dicotyledonous, used as animal feed. Examples include, without limitation, orchard grass, timothy, tall fescue, ryegrass, alfalfa, sainfoin, clovers and vetches.

As used herein, "grain feeds," means the seeds of plants that are fed to ruminant animals and may or may not include the outer hull, pod or husk of the seed. Examples include, without limitation, corn, wheat, barley sorghum, triticale, rye, canola, and Soya beans.

The present invention may be combined with other feed processing techniques or preservation methods, and may be included either during processing or preservation. Other processing techniques useful in combination with the present invention include, but not limited to, drying, ensiling, chopping, grinding, pelleting, cubing or baling in the case of forages, and in the case of grains feeds and legume seeds by drying, rolling, tempering, grinding, cracking, popping, extruding, pelleting, cubing, micronizing, roasting, flaking, cooking and or exploding. Preservation may include, but not limited to ensiling and haymaking.

The improved particulate feed additive of the invention is preferably evenly applied to the feed material. The resulting feed can either be fed immediately to livestock or stored and fed at a later time. The resulting feed composition is effective for prolonged periods of time, such as for at least three years or longer depending on the nature of the feed composition, storage conditions and the like.

In addition to feed and particulate feed additive described above, the compositions of the invention may further comprise one or more additional agents that enhance the ruminant digestive processes. Such agents include, for example, pyrodoxal 5-phosphate, fumaric acid and its salts, sorbic acid and its salts, parabenzoic acid esters, benzoic acid, polydimethyl siloxane-polyethers, unsaturated alcohols, bentonite, proteolytic and/or carbohydrase enzymes, such as glycanase, hemicellase, cellulase, pectinase, xylanase and amylase, lactic acid bacteria inoculants, such as those comprising *Lactobacillus casei, L. acidophilus, L. salivarius, L. corymiformis subsp coryniformis, L. curvatus, L. plantarum, L. brevis, L. buchneri, L. fermentum, L. viridescens, Pdiococcus acidilacti, P. cerevisiae, P. pentosaceus, Streptococcus faecalis, S. faecium, S. lactis, L.*

buchneri, L. fermentum, L. viridenscens, L. delbrueckiin, Leuconostoc cremoris, L. dextranicum, L. mesenteroides or *L. citrovorum*, and polyether carboxylic acid ionophore antibiotics, such as monensin (see, e.g., Westley, *Adv. Appl. Microbiology* **22:**177-223 (1977)). Where the surfactant is used in conjunction with exogenous glycanases, the method of producing feed compositions in the present invention is most effective when surfactant constitute on the order of about 0.01% of the dry weight of the feed. In situations where the surfactant is used without exogenous enzymes, the compositions are most effective when the surfactant concentration does not exceed about 0.2% of the dry weight of the feed.

Example 1

Accelerated Oxidation Tests

Solid silica particles (LuctaCarrier™ silica, Lucta, S.A., Barcelona, Spain) are coated 50% wt/wt (based of the combined weight of the particles and coating) with a mixture of polyethylene 20 sorbitan monooleate (Polysorbate 80) and an amount of the antioxidants set forth in the tables, below, or no antioxidant as a control. The liquid antioxidants (e.g., ethoxyquin) are mixed directly with the Polysorbate 80 at the concentrations set forth in the tables. The solid antioxidants (e.g., BHA or BHT) are dissolved in a suitable solvent (e.g., ethyl alcohol) and then mixed with the Polysorbate 80 at the listed concentration levels. The oxidative stability of the coating is then determined using the Rancimat test. Oxidative stability relates to how easily components of oil oxidize which creates off-flavors in the oil, and is measured by instrumental analysis using accelerated oxidation methods. American Oil Chemists' Society Official Method Cd 12-57 for Fat Stability: Active Oxygen Method (re'vd 1989); *Rancimat* (Laubli, M. W. and Bruttel, P. A., JOACS 63:792-795 (1986)); Joyner, N. T. and J. E. McIntyre, Oil and Soap (1938) 15:184 (modification of the Schaal oven test). The Rancimat method has been developed as the automated version of the AOM method (active oxygen method) for the determination of the induction time of fats and oils. In this method the highly volatile organic acids produced by autoxidation are absorbed in water and used to indicate the induction time. As used in the following tables, the abbreviations have the following meanings:

BHT = butylated hydroxytoluene
BHA = butylated hydroxyanisole
EQ = ethoxyquin

Table 1

Antioxidant	Concentration (ppm)	Rancimat Stability (hours)
Control	None	1.5
BHT	200	1.75
BHT + BHA	100 + 100	3.85
BHT + tocopherols	200 + 200	3.90

Table 2

Antioxidant	Concentration (ppm)	Rancimat Stability (hours)
Control	None	1.5
BHT	200	1.85
BHT + BHA	100 + 100	3.85
BHT + tocopherols	200 + 200	6.05

Table 3

Antioxidant	Concentration (ppm)	Rancimat Stability (hours)
Control	None	2.5
BHT	200	4.45
BHT + BHA	100 + 100	14.20
BHT + tocopherols	200 + 200	24.15

Table 4

Antioxidant	Concentration (ppm)	Rancimat Stability (hours)
Control	None	2.5
BHT	200	6.15
BHT + BHA	100 + 100	17.35
BHT + tocopherols	200 + 200	15.75
EQ	200	42.70
EQ	500	60.60
EQ	1000	87.50

Table 5

Antioxidant	Concentration (ppm)	Rancimat Stability (hours)
Control	None	1.70
EQ	1000	79.40

Table 6

Antioxidant	Concentration (ppm)	Rancimat Stability (hours)
Control	None	1.70
EQ	1000	97.20

Example 2
Accelerated Oxidation/ Shelf Life test

The nonionic surfactant polyoxyethylene 20 sorbitan monooleate (Polysorbate 80) is coated in an amount of 50% wt/wt onto silica particles (i.e., in the proportion 50 g. of Polysorbate 80 per 50 g. of silica), either without (control) or with added antioxidant. A shelf life test is performed by measuring, using a sensory panel, the level of rancid odor of samples stored at 40 °C., with a rancidity score being assigned to each sample (with a score of 0 for no rancid odors and 10 for highest level of rancid odors. The results are shown in Table 7, below.

Table 7

		Rancidity Score			
Antioxidant	Concentration (ppm)	1 week	2 weeks	6 weeks	10 weeks
Control		3.0	6.0	9.0	10.0
EQ	1000	1.0	2.0	3.5	5.0
BHT + EQ	200 + 200	2.0	3.5	5.0	7.5

THE EMBODIMENTS OF THE INVENTION FOR WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A feed additive for ruminant animals comprising a particulate carrier substrate and a coating on the particulate carrier substrate, the coating comprising from about 10% to about 70% (wt/wt) of a nonionic surfactant based on the combined weight of the particulate carrier substrate and coating and about 100 ppm to about 2000 ppm of an antioxidant agent based on the surfactant employed in the coating.

2. The feed additive of Claim 1, wherein the nonionic surfactant is selected from the group of polyoxyethylenesorbitan monooleate, polyoxyethylene-sorbitan trioleate, polyoxyethylenesorbitan monostearate, alkyltrimethylammonium bromides, dodecyltrimethylammonium bromide, hexadecyltrimethylammonium bromide, mixed alkyltrimethylammonium bromide, tetradecyltrimethylammonium bromide, benzalkonium chloride, benzethonium chloride, benzyldimethyldodecylammonium bromide, benzyldimethylhexadecylammonium bromide, benzyltrimethylammonium chloride, benzyltrimethylammonium methoxide, cetylpyridinium bromide, cetylpyridinium chloride, cetyltributylphosphonium bromide, cetyltrimethylammonium bromide, decamethonium bromide, dimethyldioctadecylammonium bromide, methylbenzethonium chloride, methyl mixed trialkyl ammonium chloride, methyltrioctylammonium chloride, n,n',mb'-polyethylene(10)-n-tallow-1,3-diamino-propane and 4-picoline dodecyl sulfate.

3. The feed additive of Claim 2, wherein the nonionic surfactant is selected from the group of polyoxyethylenesorbitan monooleate and polyoxyethylenesorbitan trioleate.

4. The feed additive of any one of Claims 1 to 3, wherein the nonionic surfactant comprises from about 20% to about 65% (wt/wt) of surfactant based on the combined weight of the particulate carrier substrate and coating.

5. The feed additive of any one of Claims 1 to 4, wherein the nonionic surfactant comprises from about 40% to about 60% (wt/wt) of surfactant based on the combined weight of the particulate carrier substrate and coating.

6. The feed additive of any one of Claims 1 to 5, wherein the nonionic surfactant comprises about 50% (wt/wt) of surfactant based on the combined weight of the particulate carrier substrate and coating.

7. The feed additive of any one of Claims 1 to 6, wherein the antioxidant agent is selected from the group of butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), ethoxyquin, propyl gallate, tertiary butyl hydroquinone (TBHQ) and tocopherols.

8. The feed additive of any one of Claims 1 to 7, wherein the solid particulate carrier is selected from the group of celite, diatomaceous earth and silica .

9. The feed additive of any one of Claims 1 to 8, which further comprises at least one digestion enhancing agent.

10. The feed additive of Claim 9, wherein the at least one digestion enhancing agent is a lactic acid bacteria inoculum.

11. The feed additive of Claim 9, wherein the at least one digestion enhancing agent is monensin.

12. A method of enhancing feed utilization efficiency in a ruminant animal, comprising adding to the feed of the animal a particulate feed additive to enhance the utilization of the feed by the animal, wherein the feed additive comprises a particulate carrier substrate and a coating on the particulate carrier substrate, the coating comprising from about 10% to about 70% (wt/wt) of a non-ionic surfactant based on the combined weight of the particulate carrier substrate and coating and about 100 to about 2000 ppm of an antioxidant agent based on the surfactant employed in the coating, and wherein the nonionic surfactant comprises from about 0.01 to 1 % (w/w) of the dry weight of the feed..

13. The method of Claim 12, wherein the nonionic surfactant is selected from the group of polyoxyethylenesorbitan monooleate, polyoxyethylenesorbitan trioleate, polyoxyethylenesorbitan monostearate, alkyltrimethylammonium bromides, dodecyltrimethylammonium bromide, hexadecyltrimethylammonium bromide, mixed alkyltrimethylammonium bromide, tetradecyltrimethylammonium bromide, benzalkonium chloride, benzethonium chloride, benzyldimethyldodecylammonium bromide, benzyldimethylhexadecylammonium bromide, benzyltrimethylammonium chloride, benzyltrimethylammonium methoxide, cetylpyridinium bromide, cetylpyridinium chloride, cetyltributylphosphonium bromide, cetyltrimethylammonium bromide, decamethonium

bromide, dimethyldioctadecylammonium bromide, methylbenzethonium chloride, methyl mixed trialkyl ammonium chloride, methyltrioctylammonium chloride, n,n',mb'-polyethylene(10)-n-tallow-1,3-diamino-propane and 4-picoline dodecyl sulfate.

14. The method of Claim 13, wherein the nonionic surfactant is selected from the group of polyoxyethylenesorbitan monooleate and polyoxyethylenesorbitan trioleate.

15. The method of any one of Claims 12 to 14, wherein the nonionic surfactant comprises from about 0.01 to 0.5 % (w/w) of the dry weight of the feed.

16. The method of any one of Claims 12 to 15, wherein the nonionic surfactant comprises from about 0.01 to 0.3% (w/w) of the dry weight of the feed.

17. The method of any one of Claims 12 to 16, wherein the antioxidant agent is selected from the group of butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), ethoxyquin, propyl gallate, tertiary butyl hydroquinone (TBHQ) and tocopherols.

18. The method of any one of Claims 12 to 17, wherein the particulate carrier substrate is selected from the group of celite, diatomaceous earth and silica.

19. The method of any one of Claims 12 to 18, which further comprises adding at least one digestion enhancing agent to the feed.

20. The method of Claim 19, wherein the at least one digestion enhancing agent is a lactic acid bacteria inoculum.

21. The method of Claim 20, wherein the at least one digestion enhancing agent is monensin.