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Confirming Diethylcarbamazine Levels using Near-Infrared Spectroscopy Detection in an Extruder

Abstract

A method is disclosed for producing an extruded daily ration feed product with a known concentration of diethylcarbamazine. The method involves mixing propylene glycol and diethylcarbamazine together to form an active blend with a predetermined ratio. The active blend and a feed mixture are then introduced into an extruder and forced through a die to form the extruded daily ration feed product. Inline near-infrared spectroscopy is used to detect the propylene glycol within the extruder. The detected level of propylene glycol is correlated to the concentration of diethylcarbamazine within the extruded daily ration feed product based on the predetermined ratio. This method provides a reliable and efficient way to ensure the desired concentration of diethylcarbamazine exists in the extruded daily ration feed product during the production process.

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Background/Summary

CROSS REFERENCES [0001] This U.S. Nonprovisional application claims the benefit of U.S. Provisional Application No. 63/555,439 entitled Confirming Diethylcarbamazine Levels using Near-Infrared Spectroscopy Detection in an Extruder, filed on 20 Feb. 2024, which is incorporated herein by reference in its entirety.

REFERENCE TO RESEARCH
[0002] Not Applicable.
REFERENCE TO CDS
[0003] Not Applicable.
FIELD OF THE INVENTION
[0004] The present disclosure relates to a method for producing daily ration animal feed products for household pets that include a therapeutic amount of diethylcarbamazine based on detection of propylene glycol during an extrusion process.
BACKGROUND
[0005] Animals, such as household pets, consume feed products daily. Extrusion has been employed as a rapid, continuous production process to prepare feed products, such as pet foods. Raw ingredients undergo mixing and preconditioning to ensure uniformity of a feed mixture fed into an extruder. While being extruded, the raw ingredients within the feed mixture are cooked by the high pressure, high shear, and high temperature environment created by the screws encased in the extruder barrel. The cooked product is pushed out through a small opening, called a die, to form and shape the feed mixture into an extruded feed product.
SUMMARY
[0006] In some aspects, the techniques described relate to a method including the steps of: (a) mixing propylene glycol and diethylcarbamazine together to form an active blend having a known ratio of propylene glycol to diethylcarbamazine; (b) introducing the active blend and a feed mixture into an extruder; (c) forcing the feed mixture with the active blend through the die to form an extruded daily ration feed product; and (d) detecting the propylene glycol within the extruder with inline near-infrared spectroscopy, wherein the detected level of propylene glycol correlates to the concentration of diethylcarbamazine within the extruded daily ration feed product.
[0007] In some aspects, the techniques described relate to a method, further including the step of:
[0008] (a) tracking in real time any extruded daily ration feed product that is produced while the calculated concentration of diethylcarbamazine deviates from a desired concentration.
[0009] In some aspects, the techniques described relate to a method including the steps of: (a) mixing a carrier ingredient and an active ingredient together to form an active blend having a known ratio of carrier ingredient to active ingredient; (b) introducing the active blend and a feed mixture into an extruder; and (c) detecting the carrier ingredient within the extruder.
[0010] In some aspects, the techniques described relate to a method, further including the step of:
[0011] (a) calculating the concentration of the active ingredient based on an amount of carrier ingredient detected and the known ratio of carrier ingredient to active ingredient.
[0012] In some aspects, the techniques described relate to a method, further including the step of:
[0013] (a) increasing the amount of active blend introduced into the feed mixture if the calculated concentration of the active ingredient is below a desired concentration.

[0014] In some aspects, the techniques described relate to a method, further including the step of:
[0015] (a) decreasing the amount of active blend introduced into the feed mixture if the calculated concentration of the active ingredient is above a desired concentration.
[0016] In some aspects, the techniques described relate to a method, further including the step of:
[0017] (a) forcing the feed mixture through the die to form an extruded daily ration feed product.
[0018] In some aspects, the techniques described relate to a method, further including the step of:
[0019] (a) verifying, continuously, that the extruded daily ration feed product has a desired concentration of active ingredient in real time.
[0020] In some aspects, the techniques described relate to a method, further including the step of:
[0021] (a) tracking in real time any extruded daily ration feed product that is produced while the calculated concentration of the active ingredient deviates from a desired concentration.
[0022] In some aspects, the techniques described relate to a method, further including the step of:
[0023] (a) halting the extrusion process if the active ingredient deviates from the desired concentration within the feed mixture.
[0024] In some aspects, the techniques described relate to a method, further including the step of:
[0025] (a) transferring the extruded daily ration feed product away from downstream processing if the active ingredient deviates from the desired concentration.
[0026] In some aspects, the techniques described relate to a method, wherein the detected level of carrier ingredient correlates to the concentration of active ingredient within the extruded daily ration feed product.
[0027] In some aspects, the techniques described relate to a method, wherein the active ingredient does not have an established near-infrared absorption.
[0028] In some aspects, the techniques described relate to a method, wherein detecting is accomplished by inline near-infrared spectroscopy.
[0029] In some aspects, the techniques described relate to a method, wherein a near-infrared transmitter and a near-infrared detector are mounted to an extruder before a die of the extruder.
[0030] In some aspects, the techniques described relate to a method, further including the steps of:
[0031] (a) disposing a near-infrared transmitter on a first side of the extruder; and (b) disposing a near-infrared detector on a second side of the extruder, opposite the first side.
[0032] In some aspects, the techniques described relate to a method, wherein the carrier ingredient is detected through a cross-section of the feed mixture within a die spacer of the extruder.
[0033] In some aspects, the techniques described relate to a method, wherein the carrier ingredient is soluble in the feed mixture.
[0034] In some aspects, the techniques described relate to a method, wherein the carrier ingredient is propylene glycol.
[0035] In some aspects, the techniques described relate to a method, wherein the carrier ingredient is polyethylene glycol.
[0036] In some aspects, the techniques described relate to a method, wherein the carrier ingredient is approximately 1% of the feed mixture.
[0037] In some aspects, the techniques described relate to a method, wherein the carrier ingredient is introduced into the extruder at a concentration of between 5 grams per kilogram to 50 grams per kilogram.
[0038] In some aspects, the techniques described relate to a method, wherein the active ingredient is soluble in the carrier ingredient.
[0039] In some aspects, the techniques described relate to a method, wherein the active ingredient is diethylcarbamazine.
[0040] In some aspects, the techniques described relate to a method, wherein the active ingredient is introduced into the extruder at a concentration of between 200 milligrams per kilogram to 2,000 milligrams per kilogram.
[0041] The above advantages and features are of representative embodiments only, and are

presented only to assist in understanding the invention. It should be understood that they are not to be considered limitations on the invention as defined by the claims. Additional features and advantages of embodiments of the invention will become apparent in the following description, from the drawings, and from the claims.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0042] Aspects are illustrated by way of example, and not by way of limitation, in the accompanying drawings, wherein:

[0043] FIG. **1** depicts an example diagram of a feed production process for forming an extruded daily ration feed product containing a known amount of an active ingredient.

[0044] FIG. **2** depicts a general overview of a feed production system that might be used in the feed production process.

[0045] FIG. **3** depicts an extruder having an inline near-infrared spectroscopy transmitter and detector positioned at the die spacer.

[0046] FIG. **4** depicts a flowchart of an example method for confirming that an active ingredient is introduced into an extruded daily ration feed product at a controlled concentration.

DETAILED DESCRIPTION

[0047] A method is disclosed for confirming that an active ingredient **133**, such as diethylcarbamazine (DEC), is introduced into a feed product, such as an extruded daily ration feed product **135**, at a controlled concentration. An active blend **132** is formed by mixing the active ingredient **133** with a carrier ingredient **134** at a predetermined ratio prior to an extrusion process. The active blend **132** may be introduced with a feed mixture **125** into an extruder **130** through active blend ports **232** disposed through a wall of the extruder **130**. Inline near-infrared spectroscopy detects the carrier ingredient **134** within the feed mixture **125** to determine the concentration of the active ingredient **133** inside the extruder **130** during the extrusion process. The extruded daily ration feed product **135** is actively monitored, with immediate feedback, to track inconsistent concentrations of the active ingredient **133** during the extrusion process. Real time monitoring of concentrations of the active ingredient **133** during the extrusion process allows for timely adjustment in processing parameters. Desired concentrations of the active ingredient **133** are incorporated into the final feed product without relying on post-extrusion analysis techniques, such as laboratory testing which can be time-consuming and delay timely adjustments during the extrusion process.

[0048] The method provides a comprehensive solution allowing for accurate and efficient control during the production process **100** to obtain desired concentrations of an active ingredient **133** in the extruded daily ration feed product **135**. Combination in steps of mixing the active blend **132**, introducing the active blend **132** with the feed mixture **125** into the extruder **130**, and detecting the concentration of the carrier ingredient **134**, in real time, during the extrusion process helps alleviate current limitations in producing an extruded daily ration feed product **135** with a controlled concentration of an active ingredient **133**. The method produces a daily ration feed product that may then be used in the feeding of domesticated household pets, such as cats and dogs.

[0049] The extruded daily ration feed product **135** produced by the extrusion process may contain respective quantities of protein, fat, and starch, together as part of the feed mixture **125**, with the active blend **132**. The active blend **132**, including the active and carrier ingredients, are incorporated therein into the total feed mixture, including raw ingredients, meat **122**, water **126**, steam **124**, and the dry blend **110**, which are transformed into the cooked and formed feed product. The active ingredient **133** is incorporated at therapeutically effective amounts into the final feed product which becomes part of an animal's normal diet. A household pet consuming the feed product daily receives a maintenance quantity of the active ingredient **133**, which is based on the animal's weight and dosage thresholds, so that therapeutic effects are realized without harmful side-effects.

[0050] Table 1, which follows, sets forth inclusion rates and ingredient proportions at different steps in a production process **100** of a first feed product:

TABLE-US-00001 TABLE 1 Production Step Ingredient Addition Rate Amount EXTRUSION Dry Blend kg/hr. 500.0 Emulsified Chicken kg/hr. 131.6 Salmon Oil kg/hr. 13.2 Active Blend kg/hr. 12.0 ACTIVE BLEND DEC Base grams 160.7 Propylene Glycol kg 3.42 Deionized Water kg 3.42 Total (kg) 7.17 COATING Dried Kibble kg 328.52 External Chicken Fat kg 21.4 AFB B18060 kg 7.1 Total (kg) 357.02 CONFIRMATION DEC in final product mg/kg 450 Propylene Glycol in % 0.96% final product

[0051] Table 2, which follows, sets forth inclusion rates and ingredient proportions at different steps in a production process **100** of a second feed product:

TABLE-US-00002 TABLE 2 Production Step Ingredient Addition Rate Amount EXTRUSION Dry Blend kg/hr. 1500.0 Emulsified Chicken kg/hr. 394.7 Fish Oil kg/hr. 39.5 Active Blend kg/hr. 36.0 ACTIVE BLEND DEC Base grams 1036.4 Propylene Glycol kg 9.99 Deionized Water kg 9.99 Total (kg) 21.02 COATING Dried Kibble kg 988.58 External Chicken Fat kg 65.2 AFB B18060 kg 32.6 Total (kg) 1086.38 CONFIRMATION DEC in final product mg/kg 954 Propylene Glycol in % 0.9% final product

[0052] FIG. **1** depicts a diagram of a feed production process **100** that forms an extruded daily ration feed product **135** containing a known amount of an active ingredient **133**. The continuous process may first involve providing an incoming stream of dry blend materials and an incoming stream of wet blend materials. The incoming streams of materials may be conditioned together, or separately, by a preconditioning system. Conditioning of the blend materials may be performed by preconditioning equipment such as a ribbon blender or preconditioner to ensure uniformity before blended materials enter the extruder **130** downstream of the preconditioning system.

[0053] As shown in FIG. **1**, a preconditioner **120** may receive a dry blend **110** of granular, solid materials and a wet blend **112** of raw, moist materials. Alternatively, an extruder **130** may directly receive the dry blend **110** and wet blend **112**. Preconditioner **120** may be used to pre-hydrate the blended materials and in some cases pre-cook the blended materials before feeding the blended materials into the extruder **130**. Functions of the preconditioner **120** may include moisture adjustment and precooking of the blended materials prior to extrusion. During preconditioning, blended materials may be held in a warm, moist environment where they are mixed for a prescribed time, and then discharged into the preconditioner **120** or extruder **130**. Preconditioning provides the benefits of improved product quality, reduced extruder wear, increased extruder capacity, and reduced power consumption.

[0054] The preconditioner **120** may be of a single-shaft design or a double-shaft design. The shaft, having mixing elements, may be rotated at relatively low or high speeds, resulting in retention times of 30 seconds or less, or 30 seconds or more, respectively. With the double-shaft design, the two shafts may have different dimensions, and rotate at different speeds, which results in improved mixing, and retention times of between 2 and 4 minutes. The preconditioner **120** can be operated at either atmospheric pressure or elevated pressure. Preconditioning at elevated pressure increases cooking temperatures above 100° C. to form steam, without providing an input of steam **124** which may be advantageous. During preconditioning, steam **124** and/or water **126** may be supplied to increase the temperature and moisture content of the blended materials. Steam **124** may be introduced from the bottom of the preconditioner **120** while water **126** that is hot (approximately 80-90° C.) may be added from the top through spray nozzles for uniform distribution. Alternatively, hot water **126** or liquid ingredients of the wet blend **112** may be introduced through liquid ports **220** disposed through a wall of the preconditioner **120**.

[0055] FIG. **2** shows a general overview of a feed production system **200** that might be used in the feed production process **100** depicted in FIG. **1**. The preconditioner **120** may be mounted between a dry ingredient feeder **210**, which may include a variable speed screw feeder **212** mounted to a bottom of a dry holding storage bin **214**, and the extruder **130**. The storage bin **214** may be used for the storage of the dry blend ingredients. The storage bin **214** provides a buffer of bulk material so that an extruder **130** has a continuous and stable supply of feed ingredients. The storage bin **214** may be equipped with a live bottom that has rotating blades to prevent bridging of the dry blend materials.

[0056] An incoming stream of dry blend materials may include dry farinaceous ingredients. Examples of ingredients for the dry blend **110** include flour derived from wheat, rice, and corn, corn gluten meal, poultry meal, brewer's yeast, sodium bicarbonate, ethoxyquin-O, potassium sorbate, sugar, glutamine peptide (GP), cheese powder, etc. The flow rate at which the incoming stream of dry blend material(s) is introduced into the preconditioner **120** or extruder **130** may be between 2 kilograms per hour (kg/hr.) and 2,000 kg/hr. The incoming flow rate of the dry blend material(s) may be further between 15 kg/hr. and 1,500 kg/hr., between 500 kg/hr. and 1,500 kg/hr., between 1,000 kg/hr. and 2,000 kg/hr., 200 kg/hr. and 800 kg/hr., between 20 kg/hr. and 200 kg/hr., between 30 kg/hr. and 180 kg/hr., between 40 kg/hr. and 160 kg/hr., between 50 kg/hr. and 140 kg/hr., between 60 kg/hr. and 120 kg/hr., between 70 kg/hr. and 100 kg/hr., or at approximately 80 kg/hr.

[0057] As shown in FIG. **1**, the incoming stream of dry blend materials may be mixed with incoming stream(s) of wet blend materials. The incoming stream(s) of wet blend materials may include a blend of aqueous and non-aqueous materials, such as meat **122**, including fresh, uncooked animal meat, emulsified meat such as emulsified chicken, oil **128** such as fish oil, water **126** such as deionized water, steam **124**, etc. Wet blend materials may be introduced into the preconditioner **120** or directly into the extruder **130**. In one example, the approximate flow rates at which the incoming stream of meat **122**, steam **124**, and oil **128** are introduced into the preconditioner **120** are 21.1 kg/hr. (26.3%), 19.2 kg/hr. (24%), and 35 g/min. (2.6%), respectively.

[0058] Optionally, prior to the step of preconditioning, the wet blend materials may be blended in a blender, with or without additives such as water, fat, tallow, syrup, nutraceuticals, and/or other additives such as grain- or legume-derived or dairy proteins. Wet ingredients may be metered either by volume with a volumetric meter or by mass with a mass flow meter. Liquid metering devices may include rotameters, differential pressure meters, fluid displacement meters, and velocity flow meters.

[0059] The flow rate at which the incoming stream of wet blend material(s) is introduced into the preconditioner **120** or extruder **130** may be between 1 kilogram per hour (kg/hr.) and 1,000 kg/hr. The incoming flow rate of the wet blend material(s) may be further between 50 kg/hr. and 500 kg/hr., between 100 kg/hr. and 200 kg/hr., between 300 kg/hr. and 500 kg/hr., between 2 kg/hr. and 90 kg/hr., between 4 kg/hr. and 80 kg/hr., between 6 kg/hr. and 70 kg/hr., between 8 kg/hr. and 50 kg/hr., between 10 kg/hr. and 40 kg/hr., or between 20 kg/hr. and 30 kg/hr.

[0060] Ingredient feeders used to feed the preconditioner **120** or extruder **130** may be selected from two types, a volumetric-type feeder, or a gravimetric-type feeder. Volumetric feeders deliver ingredients on a volume basis. A constant volume of the ingredients may be provided by the volumetric feeder but may not guarantee a constant mass flow rate due to changes in density of feed ingredients. Volumetric feeders of the single-screw kind provide a feed flow rate that is proportional to the screw speed. Use of a twin-screw improves feeding accuracy, but with higher manufacturing cost. Gravimetric feeders control feed flow rates based on the mass delivered. Therefore, a gravimetric feeder may be a more accurate feeding device to use in the feed production system **200**. A gravimetric feeder monitors and meters the weight of ingredients gravimetrically and adjusts the feed rate accordingly, if any deviation is detected. Gravimetric metering may give more precision than volumetric metering. Alternatively, a weigh-belt or loss-in-weight feeder may be used in the feed production system **200** for gravimetric metering.

[0061] FIG. **3** shows that the extruder **130** may receive a feed mixture **125** from the preconditioner **120**. The feed mixture **125** may be introduced through a feed hopper **304** into an inlet side or head end **233** of the extruder **130** adjacent a feed section **324**. The extruder **130** may be of single-screw design, which may be easier to maintain. Twin-screw extruders may process the feed mixture **125** with a wider range of characteristics. Screws may have segments so that various screw configurations can be achieved to meet the processing requirements of the feed products. Various screw segments may have different processing functions, such as conveying, kneading, mixing, shearing, and compression, all of which may be configured independently or in combination to meet the processing requirements for the feed product.
[0062] As shown in FIG. **1**, an active blend **132**, which may be a liquid having a known ratio of carrier ingredient **134** to active ingredient **133**, may be introduced into the extruder **130** with the feed mixture **125**. The active blend **132** may be included in the feed product for the purpose of animal consumption, with the expected result of imparting and maintaining a therapeutic benefit in the animal at a dosage threshold that is specific to the animal's weight when consumed daily. The active blend **132** may be a substance that is not normally consumed as a food or not normally used as a characteristic ingredient of food.
[0063] Prior to the active blend **132** being introduced into the extruder **130**, a known ratio of a carrier ingredient **134** to an active ingredient **133** may be mixed to form the active blend **132**. The carrier ingredient **134** of the active blend **132** may be a substance that is used to dissolve, dilute, disperse, or otherwise modify the active ingredient **133** or a flavoring, food enzyme, nutrient, and/or therapeutic drug of the active blend **132**. The carrier ingredient **134** may be added to the feed mixture **125** for nutritional, physiological, or other purposes of the feed product without altering its functioning, handling, application, or use. The carrier ingredient **134** may be soluble in the active blend **132**. The carrier ingredient **134** may be soluble or insoluble in the feed mixture **125**. The carrier ingredient **134** may be propylene glycol, polyethylene glycol, a lipid-based delivery system such as microemulsions, liposomes, solid lipid micro- or nanoparticles, a water-based delivery system, or include carriers derived from proteins or carbohydrates.
[0064] A carrier ingredient **134** used in the feed production process **100** may comprise propylene glycol. Propylene glycol may be blended with water **131** to form the carrier ingredient **134** of the active blend **132**. An active ingredient **133** blended with propylene glycol and water **131** may be easier to detect with analytical methods using near-infrared spectroscopy. The active ingredient **133** may be soluble in the carrier ingredient **134**. The carrier ingredient **134** may be soluble or insoluble in the other feed ingredients when mixed throughout the feed mixture **125**. The carrier ingredient **134** may not be present in any other ingredients introduced into the feed mixture **125**, so that the carrier ingredient **134** may be accurately detected as a component in the feed mixture **125**. Detecting the level of the carrier ingredient **134** provides an accurate correlation so that the concentration of the active ingredient **133** can be factored based on the known ratio of carrier ingredient **134** to active ingredient **133** in the active blend **132**.
[0065] In one example, the carrier ingredient **134** may be introduced into the extruder **130** at a concentration of between 5 grams per kilogram (g/kg) to 150 g/kg of the total weight of the feed mixture **125**. The concentration at which the carrier ingredient **134** is introduced into the extruder **130** may be further between 50 g/kg to 150 g/kg, between 100 g/kg to 150 g/kg, between 75 g/kg to 125 g/kg, between 5 g/kg to 50 g/kg, between 5 g/kg to 45 g/kg, between 10 g/kg to 40 g/kg, between 20 g/kg to 50 g/kg, between 15 g/kg to 45 g/kg, between 20 g/kg to 40 g/kg, between 5 g/kg to 25 g/kg, between 5 g/kg to 25 g/kg, or between 5 g/kg to 15 g/kg of the total weight of the feed mixture **125**.
[0066] In one example, the carrier ingredient **134** may be introduced into the extruder **130**, with the feed mixture **125**, at a processing rate of approximately 1% (percentages based on weight per time) of the total feed mixture processed during the feed production extrusion process. A processing rate of approximately 1% inclusion of the carrier ingredient **134** may be targeted so that after topical

ingredients are added the carrier ingredient **134** becomes diluted to less than 1% of the extruded feed product. In this case, the carrier ingredient **134** may not have to be listed on a package label. Processing rates of inclusion of the carrier ingredient **134** into the total feed mixture may be between about 0.5% to 5%, or further between about 1% to 5%, between about 1% to 3%, between about 2% to 4%, between about 3% to 5%, between about 0.5% to 1.5%, between about 0.7% to 1.3%, between about 0.6% to 1.0%, or between about 0.9% to 1.1% of the total feed mixture during the feed production extrusion process.

[0067] The active ingredient **133** of the active blend **132** may be a substance such as a food enzyme, nutrient, pharmaceutical, nutraceutical, antibiotic, steroid, analgesic, angiotensin-converting enzyme (ACE) inhibitor, anti-inflammatory agent, endoectacide (e.g. dewormer such as heartworm preventative drug), ectoparasiticide (e.g. drug effective against fleas and ticks), and/or other therapeutic drug selected from a wide range of drugs that is used to treat, maintain, prevent, or otherwise furnish pharmacological activity in the animal that consumes the active ingredient **133**. The active blend **132** may be comprised of multiple active ingredients. An active ingredient **133** may be added to the feed mixture **125** for nutritional, physiological, or other purposes of the feed product without altering its functioning, handling, application, or use. The active ingredient **133** may be soluble in the carrier ingredient **134** or the water **131** of the active blend **132**.

[0068] The active ingredient **133** may be one, or any appropriate combination, of the following ingredients such as Methoprene (insect growth regulator), Lufenuron (insect growth regulator, chemically dissimilar to Methoprene), Praziquantel (tapeworm treatment), Enrofloxacin (potent broad spectrum antibiotic), Dexamethasone (steroid of the cortisone type), Ibuprofen (non-steroidal anti-inflammatory drug) Fenbendazole (mammal dewormer), Oxytetracycline (widely used antibiotic), Ivermectin/Methoprene/Praziquantal cocktail (antiparasitical combination), Imidaccopria (imidacloprid), Amoxicillin (broad spectrum antibiotic), Tribrissen (antibiotic), Doramectin (broad spectrum dewormer and anthelmintic), Selamectin, Moxidectin, Milbemycin Oxime, Eprinomectin, or a broader range of drugs than listed here.

[0069] An active ingredient **133** that may be used in the feed production process **100** is diethylcarbamazine. For an active ingredient **133**, such as diethylcarbamazine which has a weaker near-infrared spectroscopy signature, the active ingredient **133** may be mixed with the carrier ingredient **134**. For an active ingredient **133** having a stronger near-infrared spectroscopy signature, the active ingredient **133** may be measured directly, without a carrier ingredient **134**, within the extruder **130** along an extruder barrel assembly **236** or at a die spacer **237**.

[0070] In one example, the concentration at which the active ingredient **133** is introduced into the extruder **130** may be at a concentration of between 2 milligrams per kilogram (mg/kg) to 2,000 mg/kg of the total weight of the feed mixture **125**. The concentration at which the active ingredient **133** is introduced into the extruder **130** may be further between 20 mg/kg to 1,500 mg/kg, between 200 mg/kg to 2,000 mg/kg, between 100 mg/kg to 1,000 mg/kg, between 200 mg/kg to 1,000 mg/kg, between 500 mg/kg to 1,500 mg/kg, between 700 mg/kg to 1,100 mg/kg, between 800 mg/kg to 1,100 mg/kg, between 400 mg/kg to 800 mg/kg, or between 500 mg/kg to 750 mg/kg of the total weight of the feed mixture **125**.

[0071] In one example, the active ingredient **133** may be introduced into the extruder **130**, with the feed mixture **125**, at a processing rate of approximately 0.1% (percentages based on weight per time) of the total feed mixture processed during the feed production extrusion process. A processing rate of 0.1% inclusion may be targeted so that after topical ingredients are added the active ingredient **133** becomes diluted to less than 0.1% of the extruded feed product. Processing rates of the active ingredient **133** with inclusion into the total feed mixture may be between 0.0002% to 0.2%, or further between 0.004% to 0.2%, between 0.0008% to 0.2%, between 0.001% to 0.2%, between 0.002% to 0.15%, between 0.02% to 0.2%, between 0.01% to 0.1%, between 0.02% to 0.1%, between 0.05% to 0.15%, between 0.07% to 0.11%, between 0.08% to 0.11%, or between 0.04% to 0.08% of the total feed mixture during the feed production extrusion process.

[0072] An automated mixing system may be used to mix the active blend **132** and the feed mixture **125** prior to being introduced, together, through a wall of the extruder **130**, such as through active blend ports **232** disposed in a feed section **324** of the extruder **130**. Alternatively, the automated mixing system may introduce the active blend **132** and the feed mixture **125**, separately on an individual basis, into the extruder **130**. The automated mixing system may use pumps and valves to control the flow rates of the active blend **132** and the feed mixture **125** into the extruder **130**. The automated system may improve the accuracy and consistency of the mixing process.
[0073] The active ingredient **133** may be pre-mixed throughout the carrier ingredient **134** at a known ratio prior to being introduced into the extruder **130**. The ratio may be based on concentration. The ratio of the carrier ingredient **134** to active ingredient **133** incorporated into the feed mixture **125** may be between a range of about 20,000:1 to 2:1. The ratio of carrier ingredient **134** to active ingredient **133** may be further between a range of 500:1 and 5:1, between 400:1 and 4:1, between 300:1 and 3:1, between 200:1 and 2:1, between 100:1 and 2:1, between 100:1 and 10:1, between 200:1 and 20:1, between 300:1 and 30:1, between 400:1 and 40:1, or between 500:1 and 50:1.
[0074] The active ingredient **133** may be pre-mixed throughout the carrier ingredient **134** at known concentrations prior to being introduced into extruder **130**. The concentration of active ingredient **133** to carrier ingredient **134** that is to be incorporated into the feed mixture **125** may be between about 0.4 g of active ingredient per 1 kg of carrier ingredient to about 400 g of active ingredient per 1 kg of carrier ingredient. The concentration of active ingredient to carrier ingredient may be further between about 0.8 g of active ingredient per 1 kg of carrier ingredient to about 80 g of active ingredient per 1 kg of carrier ingredient, between about 2 g of active ingredient per 1 kg of carrier ingredient to about 200 g of active ingredient per 1 kg of carrier ingredient, between about 20 g of active ingredient per 1 kg of carrier ingredient to about 200 g of active ingredient per 1 kg of carrier ingredient, between about 4 g of active ingredient per 1 kg of carrier ingredient to about 400 g of active ingredient per 1 kg of carrier ingredient, between about 40 g of active ingredient per 1 kg of carrier ingredient to about 400 g of active ingredient per 1 kg of carrier ingredient, between about 40 g of active ingredient per 1 kg of carrier ingredient to about 100 g of active ingredient per 1 kg of carrier ingredient, or any range between any combination of these concentrations.
[0075] The flow rate at which the active blend **132** is introduced into the extruder **130** may be between 0.01 kilograms per hour (kg/hr.) and 100 kg/hr. The incoming flow rate of the active blend **132** into the extruder **130** may be further between 10 kg/hr. and 80 kg/hr., between 10 kg/hr. and 60 kg/hr., between 10 kg/hr. and 40 kg/hr. between 0.2 kg/hr. and 10 kg/hr., between 0.4 kg/hr. and 8 kg/hr., between 0.6 kg/hr. and 6 kg/hr., between 0.8 kg/hr. and 4 kg/hr., between 1 kg/hr. and 2 kg/hr., or at approximately 2 kg/hr.
[0076] In one example, the active blend **132** is introduced into the feed mixture **125** in the extruder **130** at a processing rate of approximately 2.4% (percentages based on weight per time) of the total feed mixture during the feed production extrusion process. Processing rates of the active blend **132** in the total feed mixture may be between about 1% to 10%, or further between about 4% to 8%, between about 2% to 6%, between about 3% to 6%, between about 1% to 5%, between about 2% to 5%, between about 3% to 5%, between about 1% to 3%, between about 2% to 4%, or between about 2% to 3% of the total feed mixture during the feed production extrusion process.
[0077] In one example, the active blend **132** is introduced into the feed mixture **125** in the extruder **130** at a flow rate of approximately 32 grams per min (g/min.). The flow rate at which the active blend **132** is introduced into the feed mixture **125** in the extruder **130** may be between 2 g/min. and 200 g/min. The incoming flow rate of the active blend **132** may be further between 15 g/min. and 150 g/min., between 50 g/min. and 150 g/min., between 100 g/min. and 200 g/min., 20 g/min. and 80 g/min., between 2 g/min. and 20 g/min., between 30 g/min. and 180 g/min., between 40 g/min. and 160 g/min., between 50 g/min. and 140 g/min., between 60 g/min. and 120 g/min., between 70 g/min. and 100 g/min., between 10 g/min. and 100 g/min., between 20 g/min. and 40 g/min., or at

approximately 30 g/min.

[0078] The active ingredient **133**, which is incorporated into the carrier ingredient **134** to form the active blend **132**, mixes throughout the feed mixture **125** within the extruder **130** during the extrusion process. The carrier ingredient **134** may be detectable during the extrusion process. An active ingredient **133**, such as diethylcarbamazine, may be incorporated into a carrier ingredient **134**, such as a blend of propylene glycol and water **131**. Analytical methods such as near-infrared spectroscopy may allow the carrier ingredient **134** mixed throughout the feed mixture **125** to be detected so that the amount of active ingredient **133** may be calculated during the extrusion process.

[0079] The carrier ingredient **134** may be detectable within an extruder barrel **320** of the barrel assembly **236** that has a hardened liner. The barrel **320** of the extruder **130** encases the screw assembly **305** that may comprise a screw **234** or a set of screws having root diameters that increase, decrease, or a combination of both. Often, the barrel **320** is surrounded or jacketed for heating by steam **136** within a steam jacket **310** and for cooling by water **138** within a water jacket **306**. In one example, the approximate flow rate at which the incoming stream of steam **136** is introduced into the extruder **130** is 8 kg/hr. (10%). The heating can also be accomplished by mounting electrical heating units on the barrel **320**. The inner surface of the barrel **320** may be smooth, grooved, or fluted. Different shearing conditions and pressure profiles may be suited to produce the feed product based on screw configurations. A plurality of sensors that measure pressure and/or temperature, such as thermocouples, may be mounted within a plurality of ports **308**, **316** disposed along functional sections between intake and discharge ends of the barrel **320** to monitor the feed mixture **125**.

[0080] The extruder barrel assembly **236** may have two or more functional sections. As shown in FIG. **3**, three functional sections of the barrel **320** include a feed section **324**, a compression section **326**, and a metering section **328**. A continuous flow of mass forms within the barrel **320** in the feed section **324**. The feed section **324** pushes the feed mixture **125** that is incoming towards the metering section **328**. Feed mixture **125** conveyed to the metering section **328** may melt due to input of thermal energy through the wall of the extruder barrel **320**. Feed mixture **125** may be heated by an output of thermal energy from the mechanical energy exerted upon the screw assembly **305** by a drive gear reducer and thrust bearing **302** powered by a main drive motor **231** which may be enclosed within a main drive housing **230**. Additional mixing and melting of the feed mixture **125** may occur within the compression section **326**. The feed mixture **125** may be fully mixed and cooked before exiting the metering section **328** at a die assembly **238**.

[0081] The extruder barrel assembly **236** may have various injection ports, such as active blend ports **232** for injection of the active blend **132**, additional feeding ports for the feed mixture **125**, and monitoring ports for sensors that are disposed through the barrel wall along a longitudinal length of the barrel **320**. Monitoring assemblies may be stationed between shear locks **235** of any of the extruder sections and/or outside extruder sections, such as between the terminal end **239** of the screw assembly **305** and the die assembly **238**. In one example, a monitoring assembly **322** may be positioned prior to the die assembly **238** to monitor the feed mixture **125** within one of the extruder sections. In another example, a monitoring assembly **322** may be positioned after the screw assembly **305** to monitor the feed mixture **125** within the die assembly **238**. The die assembly **238** may incorporate a die spacer **237**. The die spacer **237** defines a space downstream of the metering section **328** that is between the terminal end **239** of the screw assembly **305** in the extruder barrel **320** and the upstream side of a breaker plate **318** of the die assembly **238**.

[0082] A monitoring assembly **322** may be disposed through the extruder barrel **320** to detect the level of carrier ingredient **134** therein. The carrier ingredient **134** in the feed mixture **125** is detectable within the extruder **130** during the extrusion process. The purpose of detecting the level of carrier ingredient **134** is to confirm that the level of active ingredient **133**, which is correlated to the level of carrier ingredient **134** based on a known ratio, is at the desired level of active ingredient

133 intended for the final feed product. The monitoring assembly **322** may be disposed at the terminal end **239** of the metering section **328** to monitor feed mixture **125** within the die spacer **237**. The feed mixture **125** within the extruder **130** may be monitored with remote sensing by the monitoring assembly **322**. Remote sensing may include the acquisition of visible, near infrared, and short-wave infrared images in several broad wavelength bands.

[0083] For example, whereas the active ingredient **133** may be undetectable by near-infrared spectroscopy, or insubstantially detectable at low dosage levels, the carrier ingredient **134** may be detectable by near-infrared spectroscopy. Near-infrared spectroscopy is a form of analysis using the near-infrared region of the electromagnetic spectrum called near-infrared (NIR) light. NIR spectroscopy may be used to identify and quantify different materials in the feed mixture **125**. This method may apply this specific type of analysis during the extrusion process.

[0084] As shown in FIG. **3**, the monitoring assembly **322** includes a NIR transmitter **312** and a NIR detector **332**. The NIR transmitter **312** and the NIR detector **332** are mounted inline on opposing sides of the die spacer **237**. The NIR transmitter **312** and the NIR detector **332** may be disposed downstream of the extruder barrel **320** and before a die **314** of the die assembly **238**. In one example, the NIR transmitter **312** and the NIR detector **332** are disposed within the die spacer **237** and directly downstream of the terminal end **239** of the screw **234** and upstream of the breaker plate **318**. The NIR transmitter **312** is shown mounted on a first sidewall of the extruder **130**. The NIR transmitter **312** is structured to transmit NIR light through the space disposed between the terminal end **239** of the screw assembly **305** and the interior side of the die breaker plate **318**. The NIR detector **332** is mounted on a second sidewall of the extruder **130** facing the first sidewall that is opposite. The NIR detector **332** is structured to detect any unabsorbed NIR light being transmitted through the feed mixture **125** in the space within the die spacer **237**. Alternatively, the NIR transmitter **312** and the NIR detector **332** may be mounted on the same side of the extruder **130** in a case where unabsorbed NIR light is reflected by the feed mixture **125** or a reflector on the opposing side.

[0085] Measuring the amount of NIR light scattered, reflected, absorbed, or passed through the feed mixture **125** during the extrusion process, in real time, assists in determining the feed mixture's properties, such as identifying and quantifying the feed ingredients, without having to conduct post-extrusion process analyses. For example, an absorption curve may be established for different levels of carrier ingredient **134** in the feed mixture **125** based on transmission of unabsorbed NIR light to the NIR detector **332**. The difference between the amount of transmitted NIR light and the amount of detected NIR light gives the amount of absorbed NIR light. The level of absorbed NIR light may be associated with the level of carrier ingredient **134** within the feed mixture **125**. Based on the level of carrier ingredient **134** detected, the level of active ingredient **133** may be determined based on the known ratio of carrier ingredient **134** to active ingredient **133** which is pre-determined at formation of the active blend **132**.

[0086] The NIR light passes through a cross-section of the feed mixture **125** within the extruder **130** between the NIR transmitter **312** and the NIR detector **332** for detection of the carrier ingredient **134**. The detected level of carrier ingredient **134** correlates to the concentration of the active ingredient **133** within the feed mixture **125** as it is formed into the extruded daily ration feed product **135**. The amount of absorbed NIR light by the carrier ingredient **134** may be detected within the die spacer **237** and used to determine the concentration of active ingredient **133** that has been incorporated into the feed mixture **125** during the extrusion process. With more absorption of NIR light by the carrier ingredient **134**, the more active ingredient **133** can be inferred to be within the feed mixture **125**. With less absorption of NIR light by the carrier ingredient **134**, the less active ingredient **133** can be inferred to be within the feed mixture **125**.

[0087] The concentration of active ingredient **133**, which may be undetectable during the extrusion process, may be calculated based on a detectable amount of the carrier ingredient **134** within the feed mixture **125**. Inferring the concentration of the active ingredient **133** from the calculation, which is based on the known ratio of carrier ingredient **134** to active ingredient **133**, allows real time tracking of the final feed product during the production process. Correlation between the carrier ingredient **134** and the active ingredient **133** may be based on another parameter. Other parameters, such as weight, volume, density, or pressure readings, may be detectable and utilized in the carrier ingredient **134** detection method while the active blend **132** is incorporated into the feed mixture **125** within the extruder **130**. Preset thresholds may be established for the level of carrier ingredient **134** detected to verify if deviations in the concentration of the active ingredient **133** are occurring during the production process.

[0088] Verification that a desired concentration of active ingredient **133** is being incorporated into the feed mixture **125** may occur continuously, in real time, during the production process. If the calculated concentration of the active ingredient **133** is below a desired concentration, then the amount of active blend **132** being introduced into the feed mixture **125** may be increased. If the calculated concentration of the active ingredient **133** is above a desired concentration, then the amount of active blend **132** being introduced into the feed mixture **125** may be decreased.

[0089] The feed mixture **125**, incorporating the desired amount of active ingredient **133**, may be forced through a die assembly **238** of the extruder **130** to form the extruded daily ration feed product **135**. The die assembly **238** may be mounted on the outlet end of the barrel **320**. The die assembly **238** may hold the feed mixture **125** within the extruder barrel **320**. Holding the feed mixture **125** within the extruder barrel **320** may provide time for the screw assembly **305** to impart shear energy into the feed mixture **125**. Holding the feed mixture **125** in the barrel **320** may also provide time for the monitoring assembly **322** to detect the carrier ingredient **134** through a cross section of the feed mixture **125**.

[0090] The die assembly **238** of the extruder **130** may include the die breaker plate **318**. The die breaker plate **318** is mounted at the outlet end of the barrel **320**. The die breaker plate **318** restricts and forms the feed mixture **125** into an extruded daily ration feed product **135** during the production process. Adjusting the die **314** opening, controls the pressure, retention time, and the dimensions and shape of the final feed product. The die assembly **238** may have one or more openings where the feed mixture **125** is forced through the die plate **314** to form the extruded daily ration feed product **135**.

[0091] The extruded daily ration feed product **135** may be cut into finite lengths by a cutter **240**, such as a variable speed knife. The cutter **240** may be a group of rotating knives mounted to the die plate **314**. The rotational speed of the knives may be variable or continuous. The length of the extruded pieces may be determined by the number of knives mounted on the die plate **314** and the rotational speed of the knives.

[0092] As shown in FIG. **1**, the extruded daily ration feed product **135** may transfer to a dryer **140** for drying of the extrudate. Subsequently, the extruded daily ration feed product **135** may transfer to a coater **150** for coating of the extrudate with a palatability enhancer **154** that may or may not be blended with fat **152**, such as chicken fat. Alternatively, the extruded daily ration feed product **135** may transfer to a sorting apparatus **139** for sorting and bypass of the extrudate from further downstream processing.

[0093] The active ingredient **133** may be present in the extruded daily ration feed product **135** at a level of about 2 mg/kg of the feed product, further from about 20 mg/kg to about 10,000 mg/kg of the feed product, from about 200 mg/kg to about 2,000 mg/kg of the feed product, and from about 200 mg/kg to about 1,000 mg/kg of the feed product.

[0094] Tracking the calculated concentration of active ingredient **133** during the extrusion process also provides real time identification of any deviations from a desired concentration of active ingredient **133** in the extruded daily ration feed product **135**. If the calculated concentration of active ingredient **133** processed does not correlate to the desired concentration of active ingredient **133** intended for the extruded daily ration feed product **135** produced, then the production process **100** may be discontinued. Alternatively, the extruded daily ration feed product **135** produced with a calculated concentration of active ingredient **133** that deviates from the desired concentration may be automatically tracked and sorted into a segregation bin, all without halting the production process. If the calculated concentration of active ingredient **133** processed does correlate to the desired concentration of active ingredient **133** intended for the extruded daily ration feed product **135** produced, then the production process **100** may be continued.

[0095] In one mode, where high volumes of feed product may be processed, a sorting apparatus **139** may be employed in the feed production system **200**. The sorting apparatus **139** may be disposed at a discharge end of the extruder **130** or downstream of the extruder **130**. Any extruded feed product that has an amount of carrier ingredient **134** that deviates from an acceptable established criteria may be sorted by the sorting apparatus **139**. The sorting apparatus **139** may transfer extruded feed product having deviations with a sorting apparatus **139** in order to bypass downstream processing. The extruded feed product that bypasses downstream processing may be utilized in alternative products, corrected, or discarded. Once the detection method senses a correct amount of carrier ingredient **134**, the extruded feed product may be sent to downstream processing and final packaging **160**.

[0096] FIG. **4** is a flowchart of an example method **400** for confirming that an active is introduced into an extruded daily ration feed product at a controlled concentration. An active is mixed with a carrier to form an active blend with a known ratio of carrier to active at step **410**. The active blend is introduced with a feed mixture into an extruder at step **420**. The level of carrier is detected inside the extruder at step **430**. The level of carrier may be detected within the extruder with inline near-infrared spectroscopy. The detected level of carrier may correlate to the level of active. The level of active is calculated based on the detected level of carrier at step **440**. The calculated level of active is tracked in real time during the extrusion process at step **450**. The calculated level of active is confirmed, whether it correlates with a target level of active at step **460**. Upon completion of step **460**, one of three substeps will occur. At substep **462**, the amount of active blend introduced into the extruder will be increased if the calculated level of active is below the target level. At substep **464**, the amount of active blend introduced into the extruder will be decreased if the calculated level of active is above the target level. At substep **466**, the feed mixture with active blend is flagged for sorting by a sorting apparatus if the calculated level of active is outside a desired range of the target level. The feed mixture with the active blend is forced through the die of the extruder to form an extruded daily ration feed product at step **470**. The extruded daily ration feed product is formed with a desired level of active in real time at step **480**. After the die, the extruded daily ration feed product may be packaged with confirmation of the level of active present within the feed product, without any outside analysis.

[0097] It is understood that the invention is not confined to the particular construction and arrangement of parts herein described. That although the drawings and specification set forth a preferred embodiment, and although specific terms are employed, they are used in a description sense only and embody all such forms as come within the scope of the following claims.

[0098] The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations can be made without departing from its spirit and scope. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, are possible from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims.

[0099] For the convenience of the reader, the above description has focused on a representative sample of all possible embodiments, a sample that teaches the principles of the invention and conveys the best mode contemplated for carrying it out. Throughout this application and its associated file history, when the term “invention” is used, it refers to the entire collection of ideas and principles described; in contrast, the formal definition of the exclusive protected property right is set forth in the claims, which exclusively control. The description has not attempted to exhaustively enumerate all possible variations. Other undescribed variations or modifications may be possible. Where multiple alternative embodiments are described, in many cases it will be possible to combine elements of different embodiments, or to combine elements of the embodiments described here with other modifications or variations that are not expressly described. A list of items does not imply that any or all of the items are mutually exclusive, nor that any or all of the items are comprehensive of any category, unless expressly specified otherwise. In many cases, one feature or group of features may be used separately from the entire apparatus or methods described. Many of those undescribed variations, modifications and variations are within the literal scope of the following claims, and others are equivalent.

Claims

1. A method comprising the steps of: a. mixing propylene glycol and diethylcarbamazine together to form an active blend having a known ratio of the propylene glycol to the diethylcarbamazine; b. introducing the active blend and a feed mixture into an extruder; c. forcing the feed mixture with the active blend through a die of the extruder to form an extruded daily ration feed product; and d. detecting the propylene glycol within the extruder with inline near-infrared spectroscopy, wherein a detected level of the propylene glycol correlates to a concentration of the diethylcarbamazine within the extruded daily ration feed product.
2. The method of claim 1, further comprising the step of: a. tracking in real time any extruded daily ration feed product that is produced while a calculated concentration of the diethylcarbamazine deviates from a desired concentration.
3. A method comprising the steps of: a. mixing a carrier ingredient and an active ingredient together to form an active blend having a known ratio of the carrier ingredient to the active ingredient; b. introducing the active blend and a feed mixture into an extruder; and c. detecting the carrier ingredient within the extruder.
4. The method of claim 3, further comprising the step of: a. calculating a concentration of the active ingredient based on an amount of the carrier ingredient detected and the known ratio of the carrier ingredient to the active ingredient.
5. The method of claim 4, further comprising the step of: a. increasing the amount of the active blend introduced into the feed mixture if a calculated concentration of the active ingredient is below a desired concentration.
6. The method of claim 4, further comprising the step of: a. decreasing the amount of the active blend introduced into the feed mixture if a calculated concentration of the active ingredient is above a desired concentration.
7. The method of claim 4, further comprising the step of: a. forcing the feed mixture through a die of the extruder to form an extruded daily ration feed product.
8. The method of claim 7, further comprising the step of: a. verifying, continuously, that the extruded daily ration feed product has a desired concentration of the active ingredient in real time.
9. The method of claim 7, further comprising the step of: a. tracking in real time any extruded daily ration feed product that is produced while the calculated concentration of the active ingredient deviates from a desired concentration.
10. The method of claim 9, further comprising the step of: a. transferring the extruded daily ration feed product to a sorting apparatus if the calculated concentration of the active ingredient deviates from the desired concentration.
11. The method of claim 7, wherein a detected level of the carrier ingredient correlates to the concentration of the active ingredient within the extruded daily ration feed product.
12. The method of claim 3, wherein the active ingredient does not have an established near-infrared absorption.
13. The method of claim 3, wherein the step of detecting is accomplished by inline near-infrared

spectroscopy.
14. The method of claim 3, wherein a near-infrared transmitter and a near-infrared detector are mounted to the extruder before a die of the extruder.
15. The method of claim 3, further comprising the steps of: a. disposing a near-infrared transmitter on a first side of the extruder; and b. disposing a near-infrared detector on a second side of the extruder, opposite the first side.
16. The method of claim 3, wherein the carrier ingredient is detected through a cross-section of the feed mixture within a die spacer of the extruder.
17. The method of claim 3, wherein the carrier ingredient is soluble in the feed mixture.
18. The method of claim 3, wherein the carrier ingredient is propylene glycol.
19. The method of claim 3, wherein the carrier ingredient is polyethylene glycol.
20. The method of claim 3, wherein the carrier ingredient is approximately 1% of the feed mixture.
21. The method of claim 3, wherein the carrier ingredient is introduced into the extruder at a concentration of between 5 grams per kilogram to 50 grams per kilogram of the feed mixture.
22. The method of claim 3, wherein the active ingredient is soluble in the carrier ingredient.
23. The method of claim 3, wherein the active ingredient is diethylcarbamazine.
24. The method of claim 3, wherein the active ingredient is introduced into the extruder at a concentration of between 200 milligrams per kilogram to 2,000 milligrams per kilogram of the feed mixture.
