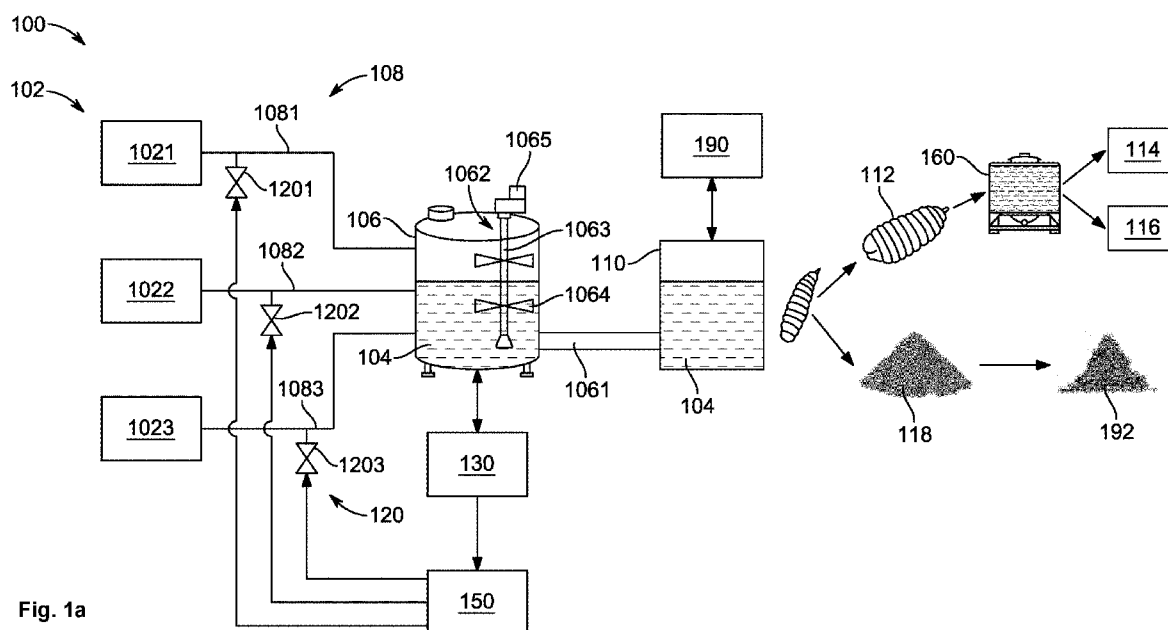




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(54) Title: INSECT BREEDING SYSTEM, OPTIMIZED FEED MIXER AND METHOD FOR MONITORING AND SELF-OPTIMIZED COMPOSING OF A FEED MEDIUM FOR INSECT BREEDING



(57) Abstract: Proposed is a system (100) and method for optimized composing of a feed medium (104) to breed insects. The system (100) comprises a feed mixer (106) for mixing ingredients to form the feed medium (104) that is associated with a feed quality to achieve an optimal growth of larvae (112) of the insect; sensors (130) disposed in the feed mixer (106) for determining measuring parameters (140) of the feed medium (104) during the mixing, where the measuring parameters (140) correspond to measurable characteristics of the feed medium (104); and a data processing device (150) that continuously monitors whether a value of each measuring parameter (1401-1405) is in a predefined range based on inputs from the sensors (130), and automatically regulates an amount of each ingredient supplied into the feed mixer (106) based on the value of each measuring parameter (1401-1405) falling in the predefined range.

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Insect Breeding System, Optimized Feed Mixer and Method for Monitoring and Self-Optimized Composing of a Feed Medium for Insect Breeding

Field of the Invention

The present invention relates to devices, systems, and methods for optimized composing of feed media for insect breeding to achieve an optimal growth of larvae of the insects by maximizing the extracted yield of protein and lipids from the larvae. In addition, present invention relates to devices, systems, and methods for monitoring the composing of feed medium by automatically regulating supply of one or more ingredients to a feed mixer to achieve a desired feed medium.

Background of the Invention

Insects for feed and food have a place in an ecological economy that investigates reciprocal barriers between natural and production systems, focusing on long-term environmental sustainability. Insects are typically raised as a feed for animals such as pets. They have also been raised as a feed for livestock such as fish, poultry, and pigs. More recently, "Entomophagy", the practice of eating insects and inclusion of edible insects in diet, has become popular. In addition, insects are a very suitable alternative to cattle feedstock. They offer an economical and sustainable solution to current issues with production and distribution of proteins for consumption. Insect farming is much cheaper and requires less energy than cattle farming. Much of this efficiency is a result of insects being exothermic. Insects obtain heat from the environment instead of having to create their own body heat as typical mammals do. Furthermore, feeding insects is cheap. Organic waste can, for example, feed large populations of insect larvae. Due to these advantages, insect farming is gaining popularity. Besides being a good source of protein, insects also have a high nutritional value, probiotic potential, and an affordable price. Furthermore, they can have high concentrations of amino acids and certain vitamins, such as vitamin B12, riboflavin, and vitamin A.

In the state-of-the-art, Insects are known to offer a unique opportunity to address challenges related to protein supply and organic waste disposal. A closed loop may be achieved on organic waste management as insects recycle nutrients that are otherwise lost and bring the nutrients back into a food chain, thereby contributing to a circular economy. Today, this sustainable solution is not only feasible, but is realized on a large scale and in an economical way. Since no fertile land is needed for breeding and harvesting of insects, a promising and sustainable alternative may be achieved.

Many insects which have maggot and/or larval stages are suitable for insect farming. Mature larvae of different types of insects can be used as protein rich food for animals or humans. For example, larvae from the *Pachnoda marginata*, also referred to as the *Pachnoda butana*, a beetle from the subfamily Cetoniina is known to have rich protein content. Other examples may include, but not limited to: [a] the *Alphitobius diaperinus*, a species of beetle in the family Tenebrionidae; [b] the *Zophobas mono*, a species of darkling beetle, whose larvae are known by the common name superworm or zophobas; [c] the mealworm beetle, *Tenebrio molitor*, a species of darkling beetle, the larvae being known as mealworms; [d] the housefly, *Musca domestica*, is a fly of the suborder Cyclorhapha, which larvae are known as maggots; [e] *Hermetia illucens*, the black soldier fly, is a common and widespread fly; [f] grasshoppers, insects of the order Orthoptera, suborder Caelifera; [g] crickets family Gryllidae (also known as "true crickets"), are insects related to grasshoppers, well-known species of this family are *Gryllus Campestris* (field cricket), *Acheta Domesticus* (house cricket), and *Gryllodes Sigillatus* (banded cricket); and [h] other insects, such as *Bombyx mori*, *Achroia girsella*, *Schistocerca americana gregaria*, *Galleria mellonella*, *Locusts migratoria migratorioides*.

A commonly known kind of insect, namely the black soldier fly (BSF), is fed with organic food waste to recycle. The BSF and mealworms are well-suited for growth on large scale. During a growth stage, the BSF does not harass human beings and animals and will not damage crops. Especially, larvae of the BSF are saprophagous and can consume a large quantity of feed materials in a short time so that they can help reduce the food waste and livestock feces effectively. Meanwhile, the larvae can digest and decompose harmful germs in the livestock feces to thereby reduce environmental hazard. In addition, feces of the larvae does not have a strong odor and can become organic fertilizer after being dried. Further, the larvae are considered as an excellent source of high quality protein owing to its high nutritive value. The insect can be used to feed animals, or separated into its component constituents of protein, oil, and chitin. Thus, the BSF has incomparable dominance over other insects and is beneficial for environmental protection.

Growing the BSFs in captivity is a function of managing two dynamic stages of its life cycle, a larval stage, and an adult stage. The adult stage of the BSF life cycle is very short, and typically lasts for only about 4 days. This stage is concerned only with seeking and securing a mate, mating, and laying eggs in a suitable location. Adult flies do not have complete mouthparts to feed. In contrast, the larval stage can last from weeks to months, and is spent in search for and consumption of food. The BSF larvae can consume up to twice their own body weight each day. In the process, the BSF larvae generates both solid and liquid waste, termed as frass and leachate, respectively. Thus, primary tasks surrounding a large-scale culture of the BSF larvae consist of devising ways to successfully feed the larvae, handle waste materials generated therein, and harvest the larvae at a desired larval or prepupal stage.

Conventional systems and methods of growing the BSF and other insect larvae includes a culture assembly, which typically involves use of flat trays or static containers established at a fixed site, for feeding the larvae. Typically, eggs and/or larvae are placed in the flat trays or the static containers. A hole or screen at a bottom surface thereof generally serves to drain away the leachate produced. The organic food waste is continuously transported to the fixed site and filled into the culture assembly after being mixed with the eggs and/or the larvae. Since the BSF larvae require an adequate supply of air, the larvae tend to stay within about 7 cm to about 10 cm of a surface of the organic food pile. Excessive amounts of food deprived of exposure to air may be subjected to a risk of undergoing anaerobic fermentation. Most studies suggest that the BSF larvae tend to avoid areas of anaerobic activity and avoid feeding in such environment. This is undesirable because it deprives feeding larvae of the organic food waste and results in incomplete consumption and utilization of feed. Anaerobic decomposition can also create foul odors and undesirable byproducts. Conventional flat trays and the static containers can also experience difficulties with temperature regulation. Both the BSF larvae and the anaerobic decomposition produce heat. An optimal growth temperature for BSF larvae is in a range of about 80 °F to about 95 °F (that is, 27 °C to 35 °C.). The larvae will seek to avoid higher temperatures by crawling away if they can and will begin to die if higher temperatures are maintained for a prolonged period. The BSF larvae also tend to be photophobic. As such, it is often desirable to cover open trays to allow the larvae to feed on the uppermost levels of the organic food pile.

However, the constant transportation of the food waste causes high transportation costs and increases processing time and labor force. Moreover, all culture processes including refilling the feed materials, adjusting the temperature and the humidity of the culture assembly, removing feces of the larvae, and collecting imagoes of black

soldier fly are executed manually, and hence adds to the cost of labor force to manage and monitor the culture assembly. Furthermore, a large number of the larvae cluster together can rub against each other during a culture operation and may result in generation of heat. If the larvae are not stirred duly to release the heat, it will cause a high temperature of the culture assembly and may result in mass mortality of the larvae owing to the high temperature. Thus, a breeding efficiency may be reduced.

Although these insects are very flexible in terms of what they can eat, a feed mix they are given should fulfill the nutritional requirements of the larvae and have the right structure to ensure a good acceptance, a short rearing duration, and a satisfactory weight gain. Feed efficiency is a result of three components, namely, quality of raw materials (such as the organic food waste), diet formulation, and nutrient absorption by the larvae. To ensure optimal performance in terms of growth parameters of the larvae, feed cost optimization, and processing productivity, a complete range of nutritional solutions have been developed in past few years. In order to define an appropriate diet formulation, it is essential to know the target composition parameters that will allow to achieve an optimal Feed Conversion Rate (FCR). As used herein, the term "feed conversion rate" may be understood as a ratio of amount of nutritional diet formulation supplied to the larvae to an amount of nutritional diet formulation absorbed by the larvae during a predefined time period. An optimal feed medium to rear the BSF in an industrial scale should have the following composition and structure:

Composition	Unit	Value
Dry matter (DM)	%	27.5 to 30
Protein	%, DM	14 to 18
Lipids	%, DM	4 to 7
Carbohydrates	%, DM	30 to 35
Fiber	%, DM	< 25
Property	Unit	Value
pH		3.5 to 4
Temperature	°C	30 to 35
Viscosity	Pa.s	10 to 14
Density	Kg/m ³	950 to 1100
Structure		
Homogeneous and Pumpable slurry		

To this end, an objective would be to efficiently nurture the larvae to their ideal harvesting weight in a shortest possible time. An ability to grow insects with minimal human interaction has been long regarded as desirable to facilitate widespread use for human consumption and/or animal consumption or for use as an intermediate lipid-based product for production of food, pharmaceuticals, and chemicals. Conventional insect feed preparation systems and methods, as described above, involves manually mixing different constituents according to a predefined recipe. Samples from such insect feed are taken offline to monitor few parameters, like water content, to thereby aid manual adjustments. However, such measurements add to the time, thereby rendering the insect feed preparation systems and methods complex and tedious.

Summary of the Invention

It is one object of the present disclosure to provide a system for composing a feed medium for optimized breeding of insects. The system includes ingredient storage units for storing ingredients required to compose the feed medium, and a feeding chamber for nurturing larvae of the type of the insect, where the larvae is fed with the ingredients to grows in size, and where the grown larvae is processed to extract proteins and lipids and frass from the processed larvae is used to form fertilizer. The system is characterized in that the system includes a feed mixer for receiving the ingredients from the ingredient storage units through multiple ingredient supply channels and mixing the ingredients to form the feed medium for the feeding chamber. The feed medium is associated with a feed quality to achieve an optimal growth of the larvae. Each ingredient supply channel extends between one ingredient storage unit and the feed mixer for supplying one ingredient to the feed mixer. The system is further characterized in that the system includes ingredient supply valves for metering an amount of ingredient passing therethrough. Each ingredient supply valve is coupled to one of the ingredient supply channels for controlling the amount of corresponding ingredient passing through the ingredient supply valve. The system is further characterized in that the system includes multiple sensors disposed in the feed mixer for determining measuring parameters of the feed medium during mixing of the ingredients in the feed mixer. The measuring parameters correspond to measurable characteristics of the feed medium. The system is further characterized in that the system includes a data processing device for receiving inputs from the sensors, determining a value of each measuring parameter of the feed medium based on the inputs from the multiple sensors, continuously monitoring whether the value of each measuring parameter is within a respective predefined range, and automatically controlling at least each ingredient supply

valve to regulate an amount of corresponding ingredient supplied into the feed mixer based on the value of each measuring parameter falling in the respective predefined range.

It is another object of the present disclosure to provide an automated method for composing a feed medium to breed insects. The automated method includes supplying ingredients from ingredient storage units through multiple ingredient supply channels and mixing the ingredients, by means of a feed mixer, to form the feed medium for a feeding chamber nurturing larvae of the insect. The larvae is fed with the feed medium to grow in size, where the feed medium is associated with a feed quality to achieve optimal growth of the larvae. The grown larvae is processed to extract proteins and lipids, and frass from the processed larvae is used to form fertilizer. Each ingredient supply channel extends between one ingredient storage unit and the feed mixer. The automated method is characterized in that the automated method includes the step of metering, by means of ingredient supply valves, an amount of ingredient passing therethrough, where each ingredient supply valve is coupled to one of the ingredient supply channels for controlling the amount of corresponding ingredient passing through the ingredient supply valve. The automated method is further characterized in that the automated method includes the step of determining, by means of sensors disposed in the feed mixer, measuring parameters of the feed medium during mixing of the ingredients in the feed mixer, where the measuring parameters correspond to measurable characteristics of the feed medium. The automated method is further characterized in that the automated method includes receiving, by means of a data processing device, inputs from the sensors, where each input corresponds to one measuring parameter of the feed medium. The automated method is further characterized in that the automated method includes determining, by means of the data processing device, a value of each measuring parameter of the feed medium based on the inputs from the sensors. The automated method is further characterized in that the automated method includes continuously monitoring, by means of the data processing device, whether the value of each measuring parameter is within a respective predefined range, and automatically controlling, by means of the data processing device, at least each ingredient supply valve to regulate an amount of corresponding ingredient supplied into the feed mixer based on the value of each measuring parameter falling in the respective predefined range.

The system and the automated method of the present disclosure provides a setup for efficiently optimize the feed medium for insects. Particularly, the data processing device of the setup determines values of the measuring parameters of the feed medium based on real-time inputs from the sensors and automatically controls the supply of the ingredient to the feed mixer when a value of at least one of the measuring parameters is not falling in the respective predefined range. In a non-limiting example, the measuring

parameters include protein content in the feed medium, the moisture content in the feed medium, pH of the feed medium, temperature of the feed medium, and viscosity of the feed medium. In summary, advantages of the present disclosure are, inter alia, that the preset system and method are able to automatically regulate the supply of the ingredient to the feed mixer based on the value of the measuring parameters of the feed medium. As such, human intervention may be avoided. Further, since the protein content in the feed medium is monitored prior to feeding the larvae, optimal protein content in the larvae puree may be achieved at the time of larvae processing for extracting the proteins and lipids.

In one or more embodiments, the system includes an image capturing device for capturing images of the larvae in the feeding chamber, and the data processing device determines growth of the larvae from captured images and automatically controls each ingredient supply valve to regulate the amount of corresponding ingredient supplied into the feed mixer based on the growth of the larvae. In some embodiments, the ingredient storage units includes a first ingredient storage unit for storing a first wet feed, a second ingredient storage unit for storing a second wet feed, and a third ingredient storage unit for storing a dry feed. In an example, the first wet feed comprises a protein source, the second wet feed comprises an energy source, and the dry feed comprises a structurizer. When the larvae does not reach an optimal growth size within a predefined time period, for example one week, the data processing device may, based on the captured images, vary the amount of the wet feeds and the dry feed in a manner to aid speedy growth of the larvae. Since the adjustments to the feed medium are performed by the data processing device automatically, the method of composing the feed medium is controllably rendered and eliminates manual steps. According to the present disclosure, the feed mixer includes a stirrer to stir the feed medium, so as to efficiently mix the ingredients and release any heat that may result during the mixing. Further, based on the type of insect and optimal feed required for that insect, data may be provided as input to the data processing device to formulate the feed medium for that insect. As such, the present disclosure provides for extending utility of the system and the method to breed, rear, and nurture various types of insects with minimum efforts between two different rearing cycles for different insects.

Other embodiment variants and advantages of the inventive system and/or method will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, which illustrate by way of example the teachings of the disclosure, and are not restrictive.

Brief Description of the Drawings

The present disclosure will be explained in more detail below relying on examples and with reference to these drawings in which:

FIG. 1A shows a schematic layout illustrating an exemplary system for composing a feed medium for a type of insect, according to some embodiments.

FIG. 1B shows a block diagram of the system, according to some embodiments.

FIG. 2 shows a flow diagram, schematically illustrating an automated method for composing a feed medium for a type of insect, according to some embodiments.

Detailed Description of the Preferred Embodiments

Aspects of this disclosure are directed to the field of commercial scale production and harvesting of insects. Particularly, the aspects of this disclosure are directed to system and methods for composing a feed medium for a type of insect to achieve optimal growth of larvae of the insects, so that extraction of proteins, lipids, and frass from the larvae may be maximized.

FIG. 1A and FIG. 1B are a schematic diagram and a block diagram, respectively, illustrating a system 100 of the present disclosure. Particularly, FIG. 1A illustrates various components of the system 100 and products extracted from the system 100, and FIG. 1B illustrates working of the components of the system 100. For the purpose of convenience and brevity, FIG. 1A and FIG. 1B are described together. The present system 100 can be implemented at an insect farming plant for breeding, rearing and/or harvesting a variety of insects. Insect farming is a recent method of producing edible insects, especially in developed countries. Insects are cultivated in captivity, and each rearing step is controlled (e.g., living conditions, diet, and food quality). Particularly, the insect farming for feed and food production are developed worldwide and has been gaining importance across several countries. As illustrated, the system 100 includes ingredient storage units 102 for storing ingredients required to formulate a feed medium 104. The ingredient storage units 102 includes a first ingredient storage unit 1021 for storing a first wet feed, a second ingredient storage unit 1022 for storing a second wet feed, and a third ingredient storage unit 1023 for

storing a dry feed. In one aspect, the first wet feed comprises a protein source, the second wet feed comprises an energy source, and the dry feed comprises a structurizer.

The system 100 further includes a feed mixer 106 for receiving the ingredients from the ingredient storage units 102. Multiple ingredient supply channels 108 aid supply of ingredients to the feed mixer 106. For example, a first ingredient supply channel 1081 extends between the first ingredient storage unit 1021 and the feed mixer 106, a second ingredient supply channel 1082 extends between the second ingredient storage unit 1022 and the feed mixer 106, and a third ingredient supply channel 1083 extends between the third ingredient storage unit 1023 and the feed mixer 106. As such, each ingredient supply channel 1081-1083 aids the supply of a corresponding ingredient to the feed mixer 106.

According to an objective of this disclosure, the feed chamber 106 mixes the ingredients to form the feed medium 104 that is supplied to a feeding chamber 110. The feeding chamber 110 nurtures larvae 112 of a type of insect. For the purpose of this disclosure, the insect is considered as *Hermetia illucens*, the black soldier fly (hereinafter referred to as "the BSF"). In other examples, other insects, such as, but not limited to, mealworms *Lepidoptera* spp, *Manduca* spp, *Bombyx* spp, *Drosophila* spp, *Anthonomus* spp, *Danaus plexippus*, *Vanessa cardui*, *Vanessa atlanta*, *Agraulus vanillae*, *Tenebrio Molitor*, and *Nymphalis antiopa* may be used. In the feeding chamber 110, the larvae 112 of the BSF is fed with the feed medium 104 to grow in size. Herein, edible insects, especially those with a short life cycle and a high re-production rate, are generally considered to be ecologically friendly food alternatives. Because insects are poikilo-thermic (ectothermic) animals that do not require energy for thermo-regulation, their feed conversion rate can be very high. Nutritional benefits include, for example, the higher content of polyunsaturated fatty acid (PUFA) together with the same protein content in comparison to common meat. More particularly, edible insects are considered herein which fulfill the request of WHO for human nutrition, thank-fully attributed to the suitable composition of essential amino acids. However, as discussed above, nutritional properties of insects depend on food and other living conditions. The nutritional value of insects is therefore not chemically constant. As an example, the above mentioned larvae of *Tenebrio molitor* (*T. molitor*) (Coleoptera: Tenebrionidae), known as mealworm, is used in the prior art as food for insectivores worldwide and therefore its basic breeding conditions are known. The advantage of the breeding of mealworms is its unpretentiousness and short life cycle. In the adult stage, the mealworm is a black beetle growing to a size of 12–15 mm, which is harmful in flour warehouses, households, and small food establishments because of ingestion of various starch-containing substrates. When used as food, it is especially valued for proteins and amino acids, especially in areas with lack of conventional protein sources.

On the example of *T. molitor*, an optimal condition can be to be reared in the temperature range of 25–27.5°C. The *T. molitor* can e.g. also be kept in a similar temperature of $28 \pm 1^\circ\text{C}$ and at a RH of $60 \pm 5\%$. However, there are typically large changes in rearing groups in dependency on the rearing temperature, in particular also in respect to the statistically significant difference of the nutritional values between the individual species with the same feed and rearing temperature. There can be observed a difference in protein, fat content, and amino acid profile. There are also differences of nutritional values in the same species and same rearing temperature, but with different feed. Thus, insects as *T. molitor* could be practically reared on different feed substrates to achieve higher nutritional values. The larvae fed with this feed are optimized by the inventive system at least to have the highest protein content, and/or dry matter yield, and/or ration of essential amino acids/nonessential amino acids ratio.

Thus, for the present inventive system, It is presumed that with the right choice of temperature and feed (diet) it is possible to influence the nutritional value of insect. The inventive system, inter alia, has the object to optimize influence of temperature and feed on the nutritional values. Part of the inventiveness of the present system lies in its broad applicability of different basic nutritional values depending on the combination of selected breeding temperatures (15, 20, and 25°C) and different types of feed (wheat bran and lentil flour) in different composition ratios.

The feed medium 104 is associated with a feed quality to achieve an optimal growth of the larvae 112. From aspects mentioned earlier, the feed medium 104 includes the protein source, the energy source, and the structurizer. In a non-limiting example, the protein source may include brewer's spent grains; the energy source may include potato peels and peels of other vegetables or fruits; and the structurizer may include soy hulls. The brewer's spent grains (BSG) is mainly composed of the husk pericarp and seed coat, which is a rich source of lignin, cellulose, hemicellulose, lipids, and protein. In particular, nutrient composition of BSG depends on barley variety, malting and mashing conditions. In general, the BSG contains 14% to 31% (dry matter) protein, 0% to 12% starch, 0% to 13% fat, and a substantial amount of hemicellulose (up to 42%, mainly arabinoxylan), cellulose (33%), and lignin (11% to 22%). Oven-dried BSG contains 15% to 24.2% protein and 3.9% ash, similar to the original barley grain, including globulins, albumins, glutelin, and hordeins. The BSG also contains a considerable quantity of vitamins, including folic acid, niacin, biotin, thiamine, choline, pantothenic acid, riboflavin, and pyridoxine. The energy source may further include organic waste from farms, pure landfill leachate and food waste, such as unused portions of fruits and vegetables which are not suitable for human consumption. In some examples, the feed medium 104 may include, but are not limited to, buckwheat seeds, soy flour, yellow corn,

sunflower kernels, dry milk, dry cabbage, lipid-rich algae, protein-rich algae, spirulina, wheat bran, rice bran, brewer's yeast, Alfalfa pellets, corn dry distiller grain, canola meal, soybean meal, peanut hulls, soybean hulls, and rice hulls.

In one aspect, the feed medium 104 may further include ingredients that are comprised of carbohydrates (e.g., starch, cellulose, sugars), vitamins, salts, lambda carrageenan, and maltodextrin. In one example, the feed medium 104 may primarily include soybean fiber and wheat germ. The soybean fiber is used as a gelling agent when dissolved in cold water. A resulting composition forms a moist paste that the larvae 112 may feed on. The soybean fiber is primarily composed of soybean cotyledons cell wall structures. Percentages of fiber in commercially available soy products can range from as low as 5% to as high as 75%. The percentages of protein can range from 1% to 14%. However, soybean fiber composition may require a sufficient amount of water to prevent the feed medium 104 from drying. In another example, the feed medium 104 may be formulated using a water absorbing agent, a nutrient or protein source, a marine colloid gelling agent, preferably, a sea weed based gelling agent, and a gelling agent carrier dispersant. The water absorbing agent may be the soybean fiber, the nutrient source may be soy flour and, preferably, wheat germ, the gelling agent may be agar or carrageenan or a combination thereof, and the gelling agent carrier dispersant may be vermiculite. Preferably, the feed medium 104 further includes USDA vitamins and preservatives, such as methyl paraben and sorbic acid. Further, the soy hulls may be added to improve texture of the feed medium 104. Particularly, the soy fiber may be in a range of about 7% to about 13%, the soy flour may be in a range of about 0% to about 5%, the agar or carrageenan or combination thereof may be in a range of about 1% to 2%, the vermiculite may be less than 1%, the wheat germ may be in a range of about 3% to about 6%, the USDA vitamins may be about 1%, the preservative may be less than 1%, and the water may be in a range of about 75% to about 85%. In yet another example, the feed medium 104 may be formulated using farm product waste.

With such feed medium, the larvae 112 grow in size, and the grown larvae is processed to extract proteins 114 and lipids 116, and frass 118 from the processed larvae is used to form fertilizer 192. Droppings/feces from the larvae 112 is commonly referred to as the frass 118. The frass 118 and cadavers of the larvae 112 represent a potentially important source of nutrients entering the soil system during a growing season of the larvae 112. The frass 118 derived from the BSF breeding is characterized by chemical and agronomic properties, which renders the frass 118 as an excellent biofertilizer without pre-post treatments. Chemical characterization of the frass 118 reveals that it has concentrations of nitrogen, potassium, and phosphorus as high as those found in farmyard manure and, especially, poultry manure, which confirms its high fertilizer potential. By contrast to

conventional mineral fertilizer, the frass 118 contains small concentrations of micronutrients (i.e., copper and zinc), which may be further beneficial for crops. However, in some aspects, the frass 118 separated from live larvae 112, and feed residue can be collected and processed or packaged for other applications (such as fertilizer or feed for other animals) in a separate area from in the insect farming plant. For example, for some fertilizer applications, the frass 118 can be composted by adding some carbon rich feedstock, such as sawdust or straw, where an amount of carbon content in the feedstock depends on insect species frass. Such composted frass can then be moistened, and a pH thereof can be adjusted to be around 7.5. Further, such frass may then be piled and turned every 48 hours until a temperature of the frass 118 starts to decrease. Such processed frass or the compost are prepared for shipment using a packaging flour machine with identification on bags.

The system 100 further includes ingredient supply valves 120 for metering an amount of ingredient passing therethrough. For example, as shown in FIG. 1B, a first ingredient supply valve 1201 is coupled to the first ingredient supply channel 1081 to meter an amount of the first wet feed passing therethrough, a second ingredient supply valve 1202 is coupled to the second ingredient supply channel 1082 to meter an amount of the second wet feed passing therethrough, and a third ingredient supply valve 1203 is coupled to the third ingredient supply channel 1083 to meter an amount of the dry feed passing therethrough. In an aspect, the ingredient supply valves 120 may be implemented as electrically actuatable valves, so that the ingredient supply valves 120 may be operated remotely. Size of the ingredient supply valves 120 and operation thereof may depend on a size of a corresponding ingredient supply channel 1081-1083. For example, the first ingredient supply channel 1081 may be embodied as a pipe having a diameter sufficient to allow a predetermined volume of the first wet feed (the protein source, grains) to be supplied therethrough and the first ingredient supply valve 1201 may be dimensioned to control the supply of the first wet feed thereacross. Similarly, the second ingredient supply channel 1082 may be embodied as a running track, operated by a motor (not shown), for carrying the second wet feed (peels of vegetables and fruits) to the feed mixer 106. Accordingly, the second ingredient supply valve 1202 may be embodied as a stopper disposed along a surface of the running track to restrict movement of the peels along the running track. Further, the third ingredient supply channel 1083 may be embodied as either a running track or an inclined pipeline integrated with a vibrator to cause movement of the dry feed (such as soy hulls) therethrough. The third ingredient supply valve 1203 may be embodied as a stopper or a gate valve capable of allowing a metered amount of soy hulls to pass thereacross.

The system 100 further includes multiple sensors 130 disposed in the feed mixer 106 for determining measuring parameters 140 of the feed medium 104 during the mixing of the ingredients in the feed mixer 106. In an embodiment, the sensors 130 may be disposed on an inner wall of the feed mixer. In another embodiment, the sensors 130 may be disposed along an outlet pipe 1061 of the feed mixer 106 that connects to the feeding chamber 110. In an embodiment, as shown in FIG. 1B, the sensors 130 may include, but are not limited to, a near-infrared sensor 1301, a radar based moisture sensor 1302, a pH sensor 1303, a temperature sensor 1304, and a viscosity sensor 1305. The measuring parameters 140 correspond to measurable characteristics of the feed medium 104. As such, the measuring parameters 140 include protein content 1401 in the feed medium 104 that is determined by the near-infrared sensor 1301, moisture content 1402 in the feed medium 104 that is determined by the radar based moisture sensor 1302, pH 1403 of the feed medium 104 that is determined by the pH sensor 1303, temperature 1404 of the feed medium 104 that is determined by the temperature sensor 1304, and viscosity 1405 of the feed medium 104 that is determined by the viscosity sensor 1305.

The system 100 further includes a data processing device 150 for monitoring and controlling operation of various components of the system 100. In an embodiment, the data processing device 150 may be a computing device capable of executing predefined instructions. In certain implementations, the computing device may be a physical device or a virtual device. In many implementations, the computing device may be any device capable of performing operations, such as a dedicated processor, a portion of a processor, a virtual processor, a portion of a virtual processor, a portion of a virtual device, or a virtual device. In some implementations, the processor may be a physical processor or a virtual processor. In some implementations, a virtual processor may correspond to one or more parts of one or more physical processors. In some implementations, instructions/logic may be distributed and executed across one or more processors, virtual or physical, to execute the instructions/logic.

The processor includes RAM, ROM, input/output (I/O) module, and memory. The I/O module may include a microphone, keypad, touch screen, and/or stylus through which a user at the insect farming plant may provide input and may also include one or more of a speaker for providing audio output and a video display device for providing textual, audiovisual, and/or graphical output. Software may be stored within a memory thereof to provide instructions to the processor(s) for enabling an integral system thereof to perform various functions. For example, the memory may store software used by the integral system, such as an operating system, application programs, and associated databases. The processor and its associated components may allow the integral system to run a series of

computer-readable instructions to analyze parameters for operating the system 100. In addition, the processor may determine an optimized process to operate various components of the system 100 herein. In some implementations, the processor may operate in a networked environment supporting connections to one or more remote clients, such as terminals, PC clients and/or mobile clients of mobile devices.

In an example, the computing device may be a computer-program product programmed for providing instructions to various components of the system 100 to actuate and operate such components. In another example, the computing device may be a computer readable medium on which program code sections of a computer program are saved, the program code sections being loadable into and/or executable in any system. The computing device may be incorporated in one or more physical packages (e.g., chips). By way of example, a physical package includes an arrangement of one or more materials, components, and/or wires on a structural assembly (e.g., a baseboard) to provide one or more characteristics such as physical strength, conservation of size, and/or limitation of electrical interaction. It is contemplated that in certain embodiments, the computing device can be implemented in a single chip.

In one embodiment, the computing device includes a communication mechanism, such as a bus for passing information among the components thereof and the components of the system 100. The processor of the computing device has connectivity to the bus to execute instructions and process information stored in the memory. The processor may include one or more processing cores with each core configured to perform independently. A multi-core processor enables multiprocessing within a single physical package. Examples of a multi-core processor include two, four, eight, or greater numbers of processing cores. Alternatively, or in addition, the processor may include one or more microprocessors configured in tandem via the bus to enable independent execution of instructions, pipelining, and multithreading. The processor may also be accompanied by one or more specialized components to perform certain processing functions and tasks such as one or more digital signal processors (DSP), or one or more application-specific integrated circuits (ASIC). A DSP typically is configured to process real-world signals (e.g., sound) in real time independently of the processor. Similarly, an ASIC can be configured to performed specialized functions not easily performed by a general purposed processor. Other specialized components to aid in performing the inventive functions described herein include one or more field programmable gate arrays (FPGA) (not shown), one or more controllers (not shown), or one or more other special-purpose computer chips.

Herein, the memory may be volatile memory and/or non-volatile memory. The memory may be coupled for communication with the processing unit. The processing unit may execute instructions and/or code stored in the memory. A variety of computer-readable storage media may be stored in and accessed from the memory. The memory may include any suitable elements for storing data and machine-readable instructions, such as read only memory, random access memory, erasable programmable read only memory, electrically erasable programmable read only memory, a hard drive, a removable media drive for handling compact disks, digital video disks, diskettes, magnetic tape cartridges, memory cards, and the like.

In an embodiment, the computing device may be communicably coupled over appropriate network to one or more user devices to receive instruction for execution. Examples of the user devices (and/or computing device) may include, but are not limited to, a personal computer, a laptop computer, a smart/data-enabled, cellular phone, a notebook computer, a tablet, a server, a television, a smart television, a media capturing device, and a dedicated network device. Appropriate network connections can, for example, include a local area network (LAN) and a wide area network (WAN) but may also include other networks. When used in a LAN networking environment, the data processing device 150 can be connected to the network through a network interface. When used in a WAN networking environment, the data processing device 150 includes means for establishing communications over the WAN, such as the Internet. The existence of any of various well-known protocols, such as TCP/IP, Ethernet, FTP, HTTP, and the like is presumed.

In some implementations, the computing device may include a data store, such as a database (for example, relational database, object-oriented database, triple store database, etc.) and may be located within any suitable memory location, such as a storage device. In some implementations, data, metadata, information, etc. described throughout the present disclosure may be stored in the data store. In some implementations, the computing device may utilize any known database management system, such as, but not limited to, DB2, in order to provide multi-user access to one or more databases, such as the above noted relational database. In some implementations, the data store may also be a custom database, such as, for example, a flat file database or an XML database. In some implementations, any other form(s) of a data storage structure and/or organization may also be used.

According to an aspect of the present disclosure, as shown in FIG. 1A and FIG. 1B, the data processing device 150 receives inputs from each of the sensors 130, particularly on a real-time basis. As used herein, the term 'real-time' refers to a usage of the memory of

the data processing device 150 (or the computing device as described earlier) to receive the inputs so that a near-spontaneous execution and/or output may be achieved. In an embodiment, each of the sensors 130 may be powered by a power supply device (not shown), such as a battery, positioned in the insect farming plant. In some embodiments, the system 100 may include a dedicated power supply device to power the components thereof, such as the feed mixer 106, motors used to operate the running tracks of the ingredient supply channels 108, the ingredient supply valves 120, the sensors 130, and the data processing device 150. In an example, the sensors 130 and the data processing device 150 may be connected through wires. In cases where the sensors 130 are disposed along the inner wall of the feed mixer 106, the wires may be routed through the wall of the feed mixer 106 and may be connected to the data processing device 150. Similar arrangement may be followed in cases where the sensors 130 are coupled to the outlet pipe 1061 of the feed mixer 106. In another example, one or more of the sensors 130 may be wirelessly connected, such as Bluetooth or via the network, to the data processing device 150. In some embodiments, the sensors 130 may be actuated by the data processing device 150 to receive the inputs. That is, the data processing device 150 may selectively at predetermined time intervals fetch inputs from each of the sensors 130.

Based on the inputs from the sensors 130, the data processing device 150 determines a value of each measuring parameter 1401-1405 of the feed medium 104. For example, based on the input from the near-infrared sensor 1301, the data processing device 150 may determine a value of protein content 1401 in the feed medium 104. For the type of insect selected, for instance the BSF, an amount of protein required to be fed through the feed medium 104 may be stored in the memory of the data processing device 150. Similarly, for each type of insect, the amount of protein required to fed may be stored as 'insect feeding data' in the memory of the data processing device 150. In an aspect, the amount of protein required to be fed may be stored as range of values. Studies have shown that insects contain about 9.96 grams to about 35.2 grams of protein per 100 grams of larvae puree 160. As such, in order to extract higher protein content from the larvae puree 160, an amount of protein supplied through the first wet feed (for example, Brewer's spent grains and/or other organic food waste) may need to be increased. It may be understood that all protein supplied through the first wet feed may not be converted into edible protein by the insect. Based on such calculations, a range for the protein content 1401 in the feed medium 104 may be predefined to obtain a required amount of protein in the larvae puree 160, and the predefined range may be stored in the memory of the data processing device 150.

After determining the value of each measuring parameter 1401-1405 of the feed medium 104, the data processing device 150 continuously monitors whether the value of

each measuring parameter 1401-1405 is within a respective predefined range. Based on the value falling in the respective predefined range, the data processing device 150 automatically controls at least each ingredient supply valve 1201-1203 to regulate the amount of the corresponding ingredient supplied into the feed mixer 106. For example, the data processing device 150 determines if the protein content 1401 in the feed medium 104 is within a corresponding predefined range. The first ingredient supply valve 1201 may be actuated by the data processing device 150 to stop the supply of the first wet feed into the feed mixer 106 when the value of the protein content 1401 in the feed medium 104 is within the corresponding range predefined for protein. As such, until the value of the protein content 1401 is within the corresponding predefined range, the first wet feed is supplied into the feed mixer 106. Similarly, based on inputs from each sensor 1301-1305, the data processing device 150 determines a value of the corresponding measuring parameter 1401-1405 and monitors whether the determined value is within the respective predefined range. Accordingly, corresponding ingredient supply valves 1201-1203 may be actuated to regulate the supply of the corresponding ingredients through respective ingredient supply channels 1081-1083. In an embodiment, such automatic adjustment in the supply of ingredients into the feed mixer 106 may be stored as instructions in the data processing device 150. The table below depicts exemplary automatic adjustment steps for various measuring parameters 140.

Composition	Unit	Value	Adjustment
Dry matter (DM)	%	27.5 to 30	If below range: add dry feedstock If above range: add water
Protein	%, DM	14 to 18	If below range: add protein rich feedstock
Lipids	%, DM	4 to 7	If below range: add lipid-rich feedstock
Carbohydrates	%, DM	30 to 35	If below range: add carbohydrate-rich feedstock
Fiber	%, DM	< 25	-
Property	Unit	Value	Adjustment
pH		3.5 to 4	If below: add alkaline pH adjusting agent If above range: add acid pH adjusting agent
Viscosity	Pa. s	10 to 14	If below range: add dry feedstock. If above range: add water

Density	Kg/m ³	950 to 1100	If below range: add dry feedstock. If above range: add water
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The feed mixer 106 includes a stirrer 1062 having a rotatable shaft 1063 and multiple blades 1064 attached to the rotating shaft 1063 to aid mixing the ingredients in the feed mixer 106. In an embodiment, the blades 1064 may be coupled to the rotatable shaft 1063 in a swivel configuration, such that efficient mixing of the ingredients may be achieved. The rotatable shaft 1063 is rotated by means of a motor 1065 located on the feed mixer 106. Electrical input to the motor 1065 may be supplied by the power supply device of the system 100. It will be apparent that adjustment of one measuring parameter 1401-1405 may affect the other. In such cases, the data processing device 150 continuously monitors variations in values of the measuring parameter 140 and performs iterations of adjustments until a desired feed medium 104 is obtained within the feed mixer 106.

In an embodiment variant, the data processing device 150 includes a display unit 1502 for displaying the value of each measuring parameter 1401-1405. In some aspects, the values are displayed in a dashboard 1504. In an example, the dashboard 1504 may display variations in values of each measuring parameter 1401-1405 until the values each respective predefined ranges.

The system 100 further includes a pH agent supply device 170 for storing an alkaline pH adjusting agent 1701 and an acid pH adjusting agent 1702. As depicted in the table above, the pH of the feed medium 104 is required to be maintained in a pH value range of 3.5 to 4. Often, due to the addition of various ingredients, the pH 1403 of the feed medium may vary. In an embodiment, the pH agent supply device 170 is connected to the feed mixer 106. Based on the input from the pH sensor 1303, the data processing device 150 determined the value of the pH 1403 of the feed medium 104. When the pH 1403 of the feed medium 104 is below the predefined pH value range, the feed medium 104 is considered acidic. As such, the data processing device 150 operates the pH agent supply device 170 to supply a calculated amount of the alkaline pH adjusting agent 1701 to the feed mixer 106. With the constant mixing by the stirrer 1062, the alkaline pH adjusting agent 1701 mixes with the feed medium to alter the pH 1403 thereof. When the data processing device 150 determines that the value of pH 1403 is within the predefined pH value range, the pH agent supply device 170 may be operated to stop the supply of the alkaline pH adjusting agent 1701. Similarly, when the pH 1403 of the feed medium 104 is above the predefined pH value range, the feed medium 104 is considered alkaline. In such cases, the data processing device 150 operates the pH agent supply device 170 to supply a calculated amount of the

acid pH adjusting agent 1702 to the feed mixer 106. With the constant mixing by the stirrer 1062, the acid pH adjusting agent 1702 mixes with the feed medium to alter the pH 1403 thereof. When the data processing device 150 determines that the value of pH 1403 is within the predefined pH value range, the pH agent supply device 170 may be operated to stop the supply of the acid pH adjusting agent 1702. As used herein, the term "calculated amount" may be understood as a quantity prompted by the data processing device 150 to the pH agent supply device 170 for supplying appropriate pH adjusting agent. In some embodiments, the pH agent supply device 170 may be actuated by the data processing device 150 to supply the required pH adjusting agent until the pH 1403 of the feed medium 104 is within the predefined pH value range. However, it will be understood that adjusting the pH 1403 may include multiple iterations with an alternating supply of minor quantities of the alkaline pH adjusting agent 1701 and the acid pH adjusting agent 1702.

The system 100 further includes a water supply device 180 having a water supply valve 1801. The water supply device 180 is connected to the feed mixer 106 and the water supply valve 1801 is controlled by the data processing device 150. The radar based moisture sensor 1302 senses the moisture content 1402 in the feed medium 104 and generates corresponding inputs. The data processing device 150 determines the value of the moisture content 1402 in the feed medium 104 based on the inputs from the radar based moisture sensor 1302. When the value of the moisture content 1402 is below a predefined moisture content range, the data processing device 150 operates the water supply valve 1801 to supply water into the feed mixer 106. With the constant mixing by the stirrer 1062, the water is mixed with the feed medium 104. When the value of the moisture content 1402 is within the predefined moisture content range, the data processing device 150 operates the water supply valve 1801 to stop supply of water into the feed mixer 106. When the value of the moisture content 1402 is above the predefined moisture content range, the data processing device 150 may operate the third ingredient supply valve 1203 to supply the dry feed into the feed mixer 106. In an embodiment, the system 100 may include a heater 184 disposed within the feed mixer 106 to add heat to the feed medium 104 when required. An electrical input to the heater 184 may be provided by the power supply device of the system 100.

In an embodiment, the ingredients may be supplied one after the other into the feed mixer 106. In another embodiment, one or more ingredients may be supplied simultaneously to the feed mixer 106. Once the values fall within the respective predefined ranges, the dashboard 1504 may display, for example, a tick mark, indicating that the corresponding measuring parameter 1401-1405 is complied with. A compliance of respective predefined ranges of all the measuring parameters 140 may be indicative of the feed quality of the feed medium 104. In an embodiment, the feed quality may also be displayed through

the dashboard 1504 on the display unit 1502. In an embodiment, the ingredients may be categorized as strategic ingredients and normal ingredients. In an example, water may be considered as the normal ingredient and others may be considered as the strategic ingredients. In one aspect, the data processing device 150 may consider that the desired feed medium 104 has been met even though the value of the moisture content 1402 may be out of the predefined moisture content range. In such cases, a number denoted for the feed quality may be few points less than an ideal case where all the measuring parameters 140 are met. This may be due to the changes in values of other measuring parameters 140 caused by the addition of water to the feed medium 104. However, the data processing device 150 may not consider the feed medium 104 as 'desired' when at least one value corresponding to the strategic ingredients are not within the respective predefined range(s).

To the user at the insect farming plant, the dashboard may help understand if the desired feed medium 104 has been achieved. In other examples, the values of each measuring parameter 1401-1405 may be displayed in other forms, such as bar graphs, pie charts, line graphs, and the like. Upon composing the desired feed medium 104 in the feed mixer 106, the data processing device 150 may actuate all the ingredient supply valves 120 to stop the supply of ingredients into the feed mixer 106. The feed medium 104 may then be supplied to the feeding chamber 110 via the outlet pipe 1061. The larvae 112 feeds on the feed medium 104. When the feed quality of the feed medium 104 is high, the optimal growth of the larvae 112 may be achieved. As used herein, the term 'optimal growth' may refer to a growth size achieved by the larvae 112. Few larvae 112 in the feeding chamber 110 may not achieve a desired growth size and may die due to non-feeding. In some embodiments, the data processing device 150 may determine size of particles in the feed medium 104. When particle size in the feed medium 104 is large, the larvae 112 may take longer than usual to feed on the feed medium 104. In order to address such instances and speed-up the feeding process, the data processing device 150 may control the motor 1065 to cause the stirrer 1062 to operate at a predefined speed to result in smaller particulate size of the ingredients in the feed medium 104. For example, size of the particles in the feed medium 104 may be ≤ 0.05 mm. Further, dead larvae may be removed from the feeding chamber 110, and the number of dead larvae may be input in the dashboard 1504 by the user. Based on such inputs, the data processing device 150, in some embodiments, may determine a larvae survival ratio, where a value is a ratio of a total number of larvae at a beginning of the feeding cycle to a total number of larvae at an end of the feeding cycle.

For the purpose of determining the optimal growth, the system 100, in an embodiment, includes an image capturing device 190 for capturing, at predefined intervals, images of the larvae 112 in the feeding chamber 110. The image capturing device 190, such

as a camera, may be disposed in the feeding chamber 110 to capture a majority area of the feeding chamber 110. The data processing device 150 determines growth of the larvae 112 from the captured images through image processing techniques known in the art. In some embodiments, the captured images of the larvae 112 may be displayed on the display unit 1502 for the user to view. In an embodiment, a template including a desired size of the larvae 112 may be stored in the memory of the data processing device 150. The desired size in the template may correspond to the optimal growth of the larvae 112. From the image processing techniques, the data processing device 150 may map the template to the captured images to determine if majority of the larvae 112 has achieved the optimal growth size. Indication regarding a number of larvae 112 attaining the optimal growth size may be displayed to the user on the display unit 1502. When a percentage of larvae 112 reaching the optimal growth size is high, it may indicate efficient feed absorption by the larvae 112 and may indicate an impact of the feed quality of the feed medium 104. In some embodiments, the data processing device 150 may determine an optimal weight of the larvae 112 in the feeding chamber 110 and may check if the optimal weight is within a predefined optimal weight range. In an example, predefined optimal weight range may be from 25 mg to about 230mg. The optimal weight may be displayed by the data processing device 150 through the dashboard 1504 on the display unit 1502.

In some aspects, the feed medium 104 may need to be supplied to the feeding chamber 110 based on the amount of the feed medium 104 remaining in the feeding chamber 110 and based on intermediate size attained by the larvae 112 in the feeding chamber 110. In some embodiments, a previously prepared feed medium 104 and the quantity of each ingredient supplied into the feed mixer 106 to prepare the previous feed medium 104 may be stored in the memory of the data processing device 150. For a subsequent preparation, the data processing device 150 may according operate each ingredient supply valve 1201-1203, the pH agent supply device 170, and the water supply valve 1801 to supply respective ingredients into the feed mixer 106 to formulate the feed medium 104 for subsequent supply into the feeding chamber 110. Upon determining that the larvae 112 in the feeding chamber has attained the optimal growth size, the data processing device 150 may automatically controls each ingredient supply valve 1201-1203, the pH agent supply device 170, and the water supply valve 1801 to either stop or regulate the amount of corresponding ingredient being supplied into the feed mixer 106. In cases where the larvae 112 do not reach a predefined intermediate size over a predefined time period, the data processing device 150 may vary the quantity of each ingredient in the feed medium 104 to aid faster growth of the larvae 112. In some embodiments, the feeding chamber 110 may be rotated at very low speed, for example 1 to 2 rotations per minute for

a set time interval, for example, 3minutes, to release the heat generated by rubbing of the larvae 112 in the feeding chamber 110.

Further, upon reaching the optimal growth size, the larvae 112 is removed from the feeding chamber 110 and processed to extract the larvae puree 160. Furthermore, the larvae puree 160 is processed to extract the proteins 114 and the lipids 116. The frass 118 from the feeding chamber 110 and frass 118 from the processed larvae is used to manufacture fertilizer 192. In an embodiment, amount of the proteins 114 extracted from the larvae puree 160 is measured. In cases where the proteins 114 extracted from every 100 gram of the larvae puree 160 is below a threshold number, a feedback may be provided by the user to the data processing device 150 through the dashboard 1504. In some aspects, the extracted protein content from 100 gram of the larvae puree 160 may be provided as input to the data processing device 150 using a keypad (not shown) of the display unit 1502. For example, a protein content in the larvae puree 160 in a range of 44% to about 60% of the protein content supplied through the feed medium 104 may be considered optimal and may indicate efficient FCR. In an embodiment, the data processing device 150 may vary the quantity of each ingredient, particularly the protein ingredient (the first wet feed), supplied to the feed mixer 106 in a subsequent cycle of preparation. In some embodiments, upon completion of each cycle of harvest, data may be collected and visualized through the dashboard 1504 on the display unit 1502. Any required changes in any of the measuring parameter 1401-1405 may be changed manually by the user. However, such human intervention may be minimum and rare. In some aspects, the lipids 116 extracted may be in a range of 28% to 36% of the amount of second wet feed supplied to the feed mixer 106.

In an embodiment variant, the system 100 may include multiple feeding chambers (such as the feeding chamber 110) to simultaneously nurture groups of larvae 112. Each of such feeding chambers may be monitored by a single data processing device (such as the single data processing device 150). Additionally, the ingredients storage units 102 may be common for all the feeding chambers and the single data processing device may control supply of the ingredients to each of the feeding chambers. In such an arrangement, a single feed mixer (such as the feed mixer 106) may be sufficient to cater to the feed medium to each of the feeding chambers. The single data processing device may accordingly control the amount of ingredients to be supplied to the feed mixer 106 based on the requirements of each of the feeding chambers. In some embodiments, each of the feeding chambers may be associated with a feeding cycle and a feed medium formulation cycle. When the feed medium for one feeding chamber is completed, a feed medium for a subsequent feeding chamber may be formulated in the feed mixer 106.

Referring now to FIG. 2, illustrated is a flowchart of an automated method 200 for composing the feed medium 102 for a type of insect, such as the BSF. FIG. 2 is described in conjunction with FIG. 1A and FIG. 1B. The teachings of the disclosed system 100 may apply *mutatis mutandis* to the present automated method 400 without any limitations. At step 2001, the automated method 200 includes supplying ingredients from ingredient storage units (such as the ingredient storage units 102) through multiple ingredient supply channels (such as the ingredient supply channels 108) and mixing the ingredients, by means of a feed mixer (such as the feed mixer 106), to form a feed medium (such as the feed medium 104) for a feeding chamber (such as the feeding chamber 110) nurturing larvae (such as larvae 112) of the type of insect. At step 2002, the automated method 200 includes metering, by means of ingredient supply valves (such as the ingredient supply valves 120), an amount of ingredient passing therethrough. At step 2003, the automated method 200 includes determining, by means of sensors (such as the sensors 130) disposed in the feed mixer, measuring parameters (such as the measuring parameters 140) of the feed medium during mixing of the ingredients in the feed mixer. At step 2004, the automated method 200 includes receiving, by means of a data processing device (such as the data processing device 150), inputs from the sensors, where each input corresponds to one measuring parameter of the feed medium. At step 2005, the automated method 200 includes determining, by means of the data processing device, a value of each measuring parameter of the feed medium based on the inputs from the sensors. At step 2006, the automated method 200 includes continuously monitoring, by means of the data processing device, whether the value of each measuring parameter is in a predefined range. At step 2007, the automated method 200 includes automatically controlling, by means of the data processing device, at least each ingredient supply valve to regulate an amount of corresponding ingredient supplied into the feed mixer based on the value of each measuring parameter falling in the predefined range.

The system and method of the present disclosure provide means for composing the feed medium for any type of insect. Additionally, the system and method of the present disclosure provide for a large-scale, modular, easily manufacturable, energy efficient, reliable, computer operated insect feeding facility that may be extensively deployed to harvest any edible insect for human and animal consumption, and for the extraction and use of proteins and lipids for applications involving medicine, nanotechnology, consumer products, and chemical production with minimal water, feedstock, and environmental impact. Responsive to the real-time receipt of inputs from the sensors, the data processing device of the system may be able to regulate the ingredients in the feed medium by controlling the supply of corresponding ingredients into the feed mixer. Such closed feedback loop allows for efficient planning and supply of ingredients (or, feedstock) to the feed mixer. Since the supply of the ingredients into the feed mixer is controlled and

regulated, the feedstock sources are efficiently used, and wastage may be reduced. With such method of formulation, a consistent feed medium for larvae may be achieved, thereby maintaining a high feed quality. As such, high feed conversion ratio may also be achieved, resulting in an efficient production of larvae for further processing as described earlier. To this, the present disclosure provides an integrated system for measuring and adjusting various measuring parameters of the feed medium for insects.

Obviously, numerous modifications and variations of the present disclosure are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the present disclosure may be practiced otherwise than as specifically described herein.

While various embodiment variants of the methods and systems have been described, these embodiments are illustrative and in no way limit the scope of the described methods or systems. Those having skill in the relevant art can effect changes to form and details of the described methods and systems without departing from the broadest scope of the described methods and systems. Thus, the scope of the methods and systems described herein should not be limited by any of the illustrative embodiments and should be defined in accordance with the accompanying claims and their equivalents.

Reference List

- 100 System
 - 102 Ingredient storage units
 - 1021 first ingredient storage unit
 - 1022 second ingredient storage unit
 - 1023 third ingredient storage unit
 - 104 Feed medium with a specific composition
 - 106 Feed mixer
 - 1061 Outlet pipe
 - 1062 Stirrer
 - 1063 rotatable shaft
 - 1064 Blades
 - 1065 Motor
 - 108 Ingredient supply channels
 - 1081 First ingredient supply channel
 - 1082 Second ingredient supply channel
 - 1083 Third ingredient supply channel
 - 110 Feeding chamber
 - 112 larvae
 - 114 Proteins
 - 116 Lipids
 - 118 Frass
 - 120 Ingredient supply valves
 - 1201 First ingredient supply valve
 - 1202 Second ingredient supply valve
 - 1203 Third ingredient supply valve
 - 130 Sensors
 - 1301 near-infrared sensor
 - 1302 radar based moisture sensor
 - 1303 pH sensor
 - 1304 temperature sensor
 - 1305 viscosity sensor
 - 140 Measuring parameters
 - 1401 protein content
 - 1402 moisture content

- 1403 pH
- 1404 temperature
- 1405 viscosity
- 150 Data processing device
 - 1502 Display unit
 - 1504 Dashboard
- 160 Larvae puree
- 170 pH agent supply device
 - 1701 alkaline pH adjusting agent
 - 1702 acid pH adjusting agent
- 180 water supply device
 - 1801 water supply valve
- 184 heater
- 190 Image capturing device
- 192 Fertilizer
- 200 Automated method
 - 2001 Step
 - 2002 Step
 - 2003 Step
 - 2004 Step
 - 2005 Step
 - 2006 Step
 - 2007 Step

Claims

1. A breed system (100) for optimized composing of a feed medium (104) for insects to enable optimal growth of larvae (112) of the insects, wherein larvae (112) of the insects are processed by extracting proteins (114) and lipids (116) and frass (118) from the processed larvae (112), the frass (118) being used to form fertilizer (192), and the system (100) comprising ingredient storage units (102) for storing ingredients required to compose the feed medium (104) and a feeding chamber (110) for nurturing larvae (112) of the insect, wherein the larvae (112) are fed with the feed medium (104) to grow, characterized,

in that the system (100) comprises a feed mixer (106) for receiving the ingredients from the ingredient storage units (102) through multiple ingredient supply channels (108) and mixing the ingredients to form the feed medium (104) supplied to the feeding chamber (110), wherein the feed medium (104) and/or the ingredients are associated with measuring parameters (140) monitored to achieve an optimal growth of the larvae (112), and wherein each ingredient supply channel (1081-1083) extends between one ingredient storage unit (1021-1023) and the feed mixer (106) for supplying one ingredient to the feed mixer (106);

in that the system (100) comprises ingredient supply valves (120) for metering an amount of ingredient passing therethrough, wherein each ingredient supply valve (1201-1203) is coupled to one of the ingredient supply channels (1081-1083) for controlling the amount of corresponding ingredient passing through the ingredient supply valve (1201-1203);

in that the system (100) comprises multiple sensors (130) disposed in the feed mixer (106) for determining measuring parameters (140) of the feed medium (104) during mixing of the ingredients in the feed mixer (106), wherein the measuring parameters (140) correspond to measurable characteristics of the feed medium (104) and/or the ingredients;

in that the system (100) comprises a data processing device (150), wherein measuring parameter values from the sensors (130) are transmitted to the data processing device (150) measuring one or more of the measuring parameter (1401-1405) of the feed medium (104), wherein the measured values of the measuring parameters (1401-1405) are continuously monitoring to be within a respective predefined value range, and wherein at least each ingredient supply valve (1201-1203, 1801) is automatically controlled by regulating an amount of corresponding ingredient supplied into the feed mixer (106) based on the value of measuring parameters (1401-1405) falling in the respective predefined range.

2. The system (100) according to claim 1, characterized in that the multiple sensors (130) comprises a near-infrared sensor (1301), a radar based moisture sensor (1302), a pH sensor (1303), a temperature sensor (1304), and/or a viscosity sensor (1305).

3. The system (100) according to claim 1 or 2, characterized in that the data processing device (150) receives real-time inputs from the sensors (130).

4. The system (100) according to claim 1, characterized in that the measuring parameters (140) comprises protein content (1401) in the feed medium (104), moisture content (1402) in the feed medium (104), pH (1403) of the feed medium (104), temperature (1404) of the feed medium (104), and viscosity (1405) of the feed medium (104).

5. The system (100) according to claim 4, characterized in that the data processing device (150) comprises a display unit (1502) for displaying the value of each measuring parameter (1401-1405) in a dashboard (1504).

6. The system (100) according to one of claims 4 to 5, characterized in that the sensors (130) are disposed in an outlet pipe (1061) of the feed mixer (106).

7. The system (100) according to claim 1, characterized in that the system (100) comprises an image capturing device (190) for capturing, at predefined intervals, images of the larvae (112) in the feeding chamber (110).

8. The system (100) according to claim 7, characterized in that the data processing device (150) determines growth of the larvae (112) from the captured images and automatically controls each ingredient supply valve (1201-1203, 1801) to regulate the amount of corresponding ingredient supplied into the feed mixer (106) based on the growth of the larvae (112).

9. The system (100) according to one of claims 1 to 8, characterized in that the ingredient storage units (102) comprises a first ingredient storage unit (1021) for storing a first wet feed, a second ingredient storage unit (1022) for storing a second wet feed, and a third ingredient storage unit (1023) for storing a dry feed.

10. The system (100) according to claim 9, characterized in that the first wet feed comprises a protein source, the second wet feed comprises an energy source, and the dry feed comprises a structurizer.

11. The system (100) according to one of claims 1 to 10, characterized in that the system (100) comprises a water supply device (180) having a water supply valve (1801), wherein the water supply device (180) is connected to the feed mixer (106) and the water supply valve (1801) is controlled by the data processing device (150), and wherein the data processing device (150) operates the water supply valve (1801) to supply water into the feed mixer (106) based on moisture content (1402) in the feed medium (104) being below a predefined moisture content range.

12. The system (100) according to one of claims 1 to 10, characterized in that the system (100) comprises a pH agent supply device (170) for storing an alkaline pH adjusting agent (1701) and an acid pH adjusting agent (1702), wherein the pH agent supply device (170) is connected to the feed mixer (106), and wherein the data processing device (150) operates the pH agent supply device (170) to supply a calculated amount of the alkaline pH adjusting agent (1701) when the pH (1403) of the feed medium (104) is below a predefined pH value range or a calculated amount of the acid pH adjusting agent (1702) when the pH (1403) of the feed medium (104) is above the predefined pH value range.

13. An automated method (200) for steering the composition of a feed medium (104) for breeding larvae (112) of insects, the larvae (112) having an optimal growth, wherein the larvae (112) are processed by extracting proteins (114) and lipids (116) and frass (118) from the processed larvae (112), the frass (118) being used to form fertilizer (192), the automated method (200) comprising the steps of:

supplying ingredients from ingredient storage units (102) through multiple ingredient supply channels (108) and mixing the ingredients, by means of a feed mixer (106), to form the feed medium (104) for a feeding chamber (110) nurturing larvae (112) of the insect, wherein the larvae (112) is fed with the feed medium (104) to grows in size, and wherein the feed medium (104) is associated with a feed quality to achieve the optimal growth of the larvae (112), and wherein each ingredient supply channel (1081-1083) extends between one ingredient storage unit (1021-1023) and the feed mixer (106), characterized,

in that, the automated method (200) comprising the step of metering, by means of ingredient supply valves (120), an amount of ingredient passing therethrough, wherein each ingredient supply valve (1201-1203) is coupled to one of the ingredient supply channels (108) for controlling the amount of corresponding ingredient passing through the ingredient supply valve (1201-1203);

in that, the automated method (200) comprising the step of determining, by means of sensors (130) disposed in the feed mixer (106), measuring parameters (140) of the feed medium (104) during mixing of the ingredients in the feed mixer (106), wherein the measuring parameters (140) correspond to measurable characteristics of the feed medium (104);

in that, the automated method (200) comprising the step of receiving, by means of a data processing device (150), inputs from the sensors (130), wherein each input corresponds to one measuring parameter (1401-1405) of the feed medium (104);

in that, the automated method (200) comprising the step of determining, by means of the data processing device (150), a value of each measuring parameter (1401-1405) of the feed medium (104) based on the inputs from the sensors (130);

in that, the automated method (200) comprising the step of continuously monitoring, by means of the data processing device (150), whether the value of each measuring parameter (1401-1405) is within a respective predefined range; and

in that, the automated method (200) comprising the step of automatically controlling, by means of the data processing device (150), at least each ingredient supply valve (1201-1203, 1801) to regulate an amount of corresponding ingredient supplied into the feed mixer (106) based on the value of each measuring parameter (1401-1405) falling in the respective predefined range.

14. The automated method (200) according to claim 13, further comprising:

displaying, by means of a display unit (1502) of the data processing device (150), the value of each measuring parameter (1401-1405) in a dashboard (1504).

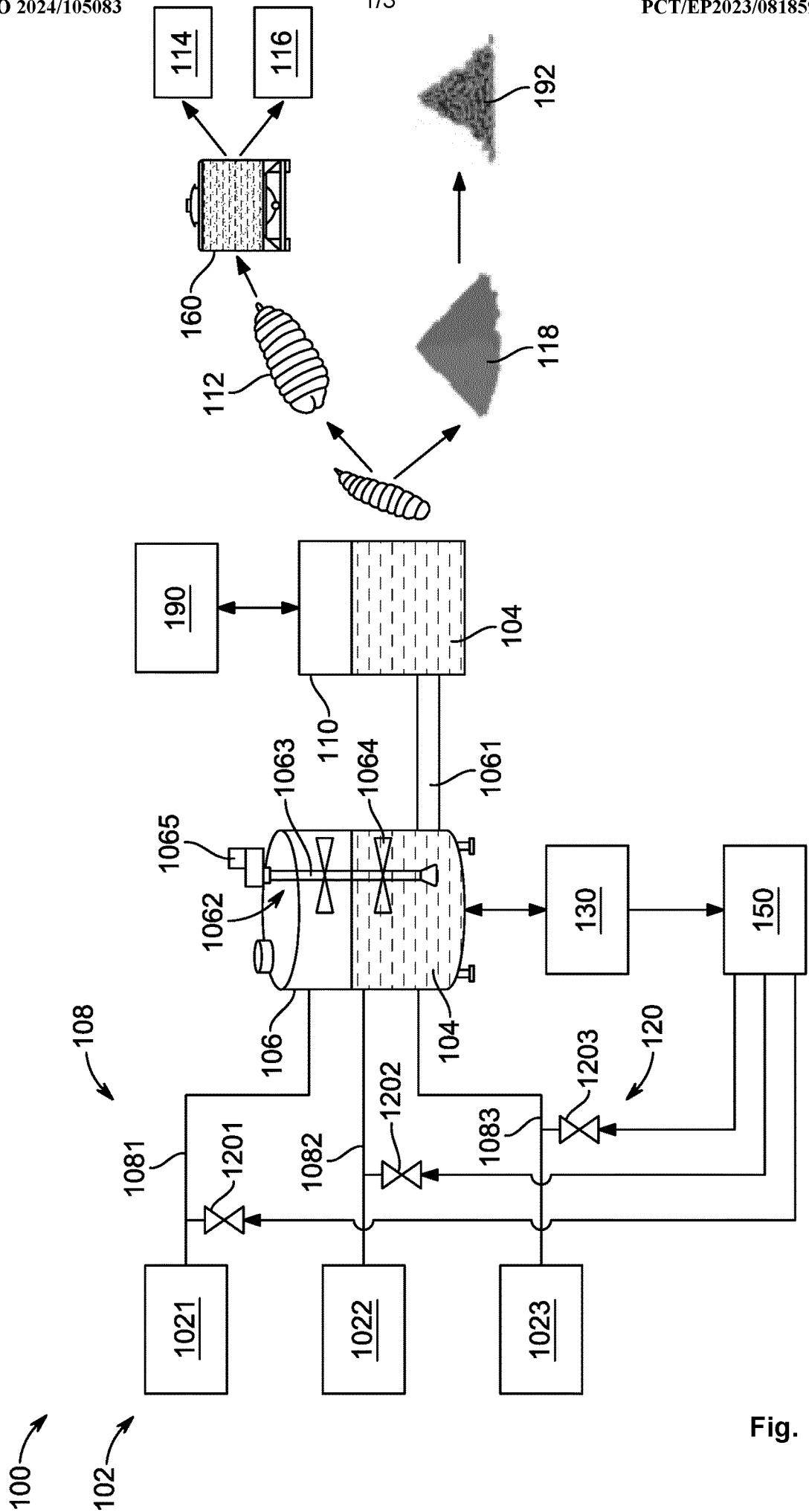
15. The automated method (200) according to claim 13 to 14, further comprising:

capturing, by means of an image capturing device (190) images of the larvae (112) in the feeding chamber (110) at predefined intervals.

16. The automated method (200) according to claim 13 to 15, further comprising:

determining, by means of the data processing device (150), growth of the larvae (112) from the captured images; and

automatically controlling, by means of the data processing device (150), at least each ingredient supply valve (1201-1203, 1801) to regulate the amount of corresponding ingredient supplied into the feed mixer (106) based on the growth of the larvae (112).



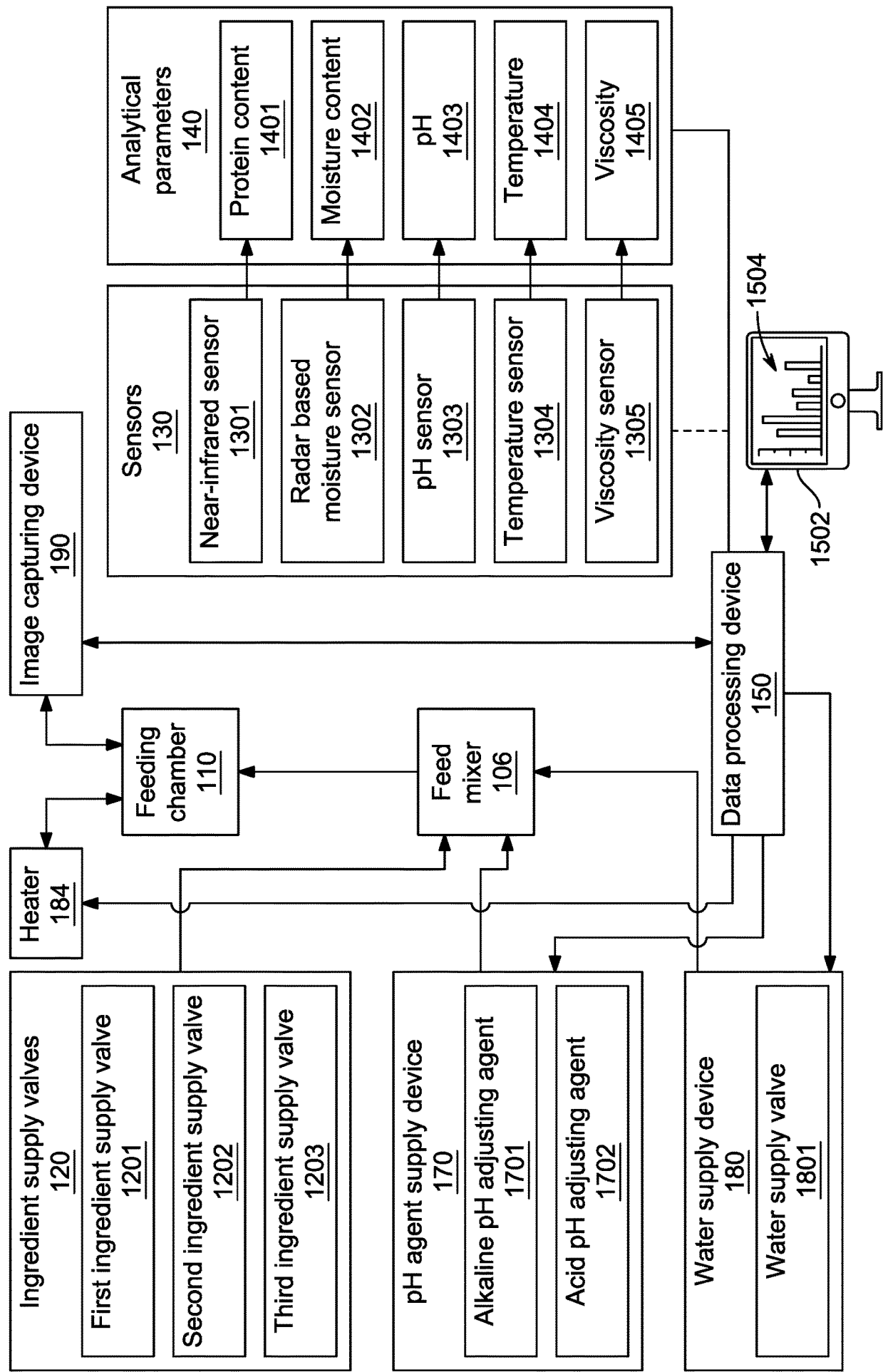


Fig. 1b

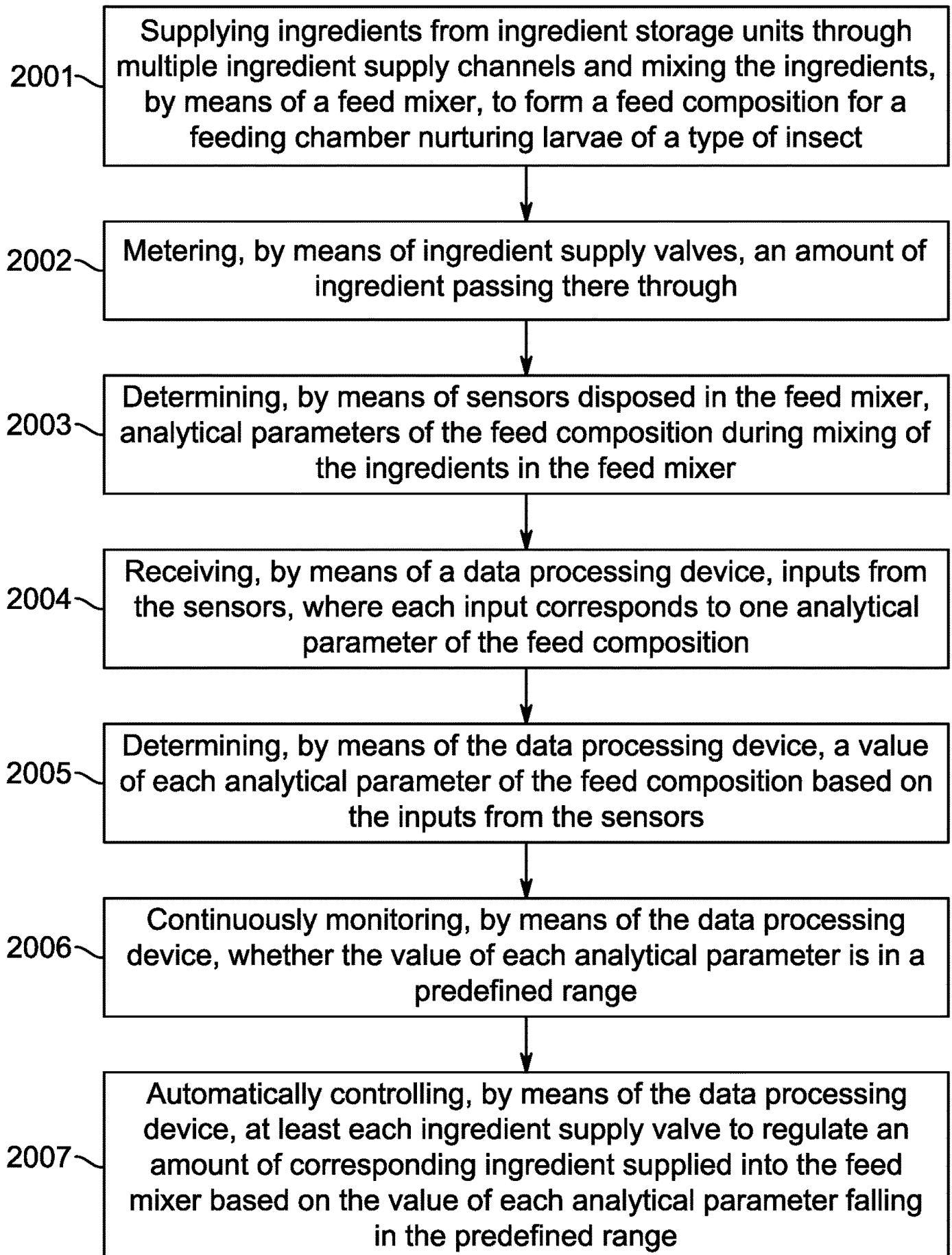


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2023/081859

A. CLASSIFICATION OF SUBJECT MATTER

INV. A23K50/90 A01K67/033

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A01K A23K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2021/137137 A1 (LEO DANIEL MICHAEL [US]) 13 May 2021 (2021-05-13)	1-6, 9-14
Y	paragraphs [0301], [0380], [0387], [0389] - [0391], [0405], [0406] -----	7, 8, 15, 16
Y	US 2020/253176 A1 (FOTIADIS FOTIS [GB]) 13 August 2020 (2020-08-13) paragraphs [0073], [0122]; figure 2 -----	7, 8, 15, 16
Y	US 2018/092339 A1 (MASSARO PETER [US] ET AL) 5 April 2018 (2018-04-05) paragraphs [0089], [0090] -----	7, 8, 15, 16
A	US 2020/323173 A1 (SABEG KARIM [BE] ET AL) 15 October 2020 (2020-10-15) paragraphs [0058], [0060], [0091] -----	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

8 February 2024

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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