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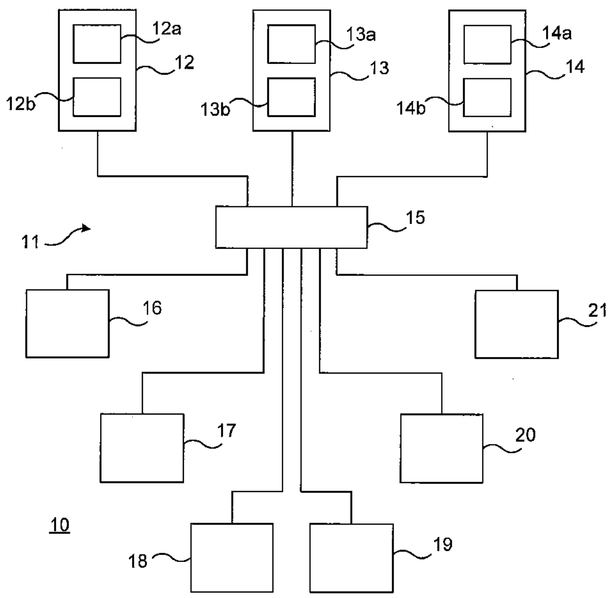

Fig. 1

(57) Abstract: A system (n) is provided for estimating the solid feed consumption of at least one animal, wherein the solid feed comprises sodium and/or potassium. The system comprises at least one temperature sensor (12b, 13b, 14b) for measuring the forestomach temperature of at least one animal, and a processing device (15) is configured to receive the measured reticulorumen temperatures from said at least one temperature sensor (12b, 13b, 14b),. The processing device is configured to receive a value of the content of sodium and/or potassium in the solid feed, receive a value of the temperature of the drinking water, and estimate the solid feed consumption of each of the at least one animals based on the variation in forestomach temperature of the animal together with the received values of the content of sodium and/or potassium in the solid feed and the temperature of the drinking water.

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SYSTEM AND METHOD FOR ESTIMATING THE SOLID FEED CONSUMPTION OF AT LEAST ONE ANIMAL, ARRANGEMENT FOR MANAGING ANIMALS, AND METHOD OF FEEDING ANIMALS

TECHNICAL FIELD

The technical field relates generally to systems and methods for estimating the solid feed consumption of at least one animal, to arrangements for managing animals, and to methods of feeding animals on a farm.

RELATED ART

The by far highest single cost on a dairy farm is the feed cost. Feed efficiency measured as kilogram of milk per kilogram of feed varies immensely between herds. Studies of herds with basically the same feed composition show a range between 1.1 to 1.8, with an average of 1.4 on herd level.

Further, feed efficiency is closely associated with the environmental load per kilogram of milk from the dairy production.

It is therefore extremely important to keep track of feeding efficiency on both individual and group level. Globally, most of the ingested feed in dairy production is emanating from a TMR (total mixed ration) on the feeding table and thus not possible to trace down to an individual animal, which would not only be important in terms of feeding efficiency, but also would be an extremely powerful instrument to identify animals at risk of having disturbances, to estimate the severity of a disease and also to follow animals on the recovery from diseases.

Today, only research herds possess facilities where feed consumption can be accurately measured. To overcome this gap, tools to estimate feeding time as a proxy to feed consumption have been developed. However, as the feeding speed varies considerably between individual animals, the evaluation of feed consumption is highly inaccurate.

SUMMARY

It is an aim of this document to reveal novel systems and methods for estimating the solid feed consumption, or dry matter intake, by animals, e.g. cows, on a farm on an animal individual level, which are accurate, precise, and easy to implement on full size commercial farms.

A first aspect refers to a system for estimating the solid feed consumption of at least one animal, wherein the solid feed comprises sodium and/or potassium. The system comprises at least one temperature sensor for measuring the forestomach temperature of at least one animal, and a processing device is configured to receive the measured forestomach temperatures from said at least one temperature sensor. The processing device is further configured to receive a value of the content of sodium and/or potassium in the solid feed, receive a value of the temperature of the drinking water, and estimate the solid feed consumption of each of the at least one animals based on the variation in forestomach temperature of the animal together with the received values of the content of sodium and/or potassium in the solid feed and of the temperature of the drinking water. The forestomach is preferably the reticulum, and the forestomach temperature is preferably the reticulorumen temperature.

It has been discovered that the amount of urine produced by an animal correlates well with the mineral intake of the animal. Since the amount of urine produced correlates strongly with the water intake, the dry matter intake can be estimated from the water intake on an animal individual level, if the mineral content (sodium and/or potassium) of the feed is known. It has also been discovered that water intake affects forestomach temperature, especially reticulorumen temperature, for cows. The variation in forestomach temperature can therefore be used to estimate the water intake, and thus also to estimate the dry matter intake, if the mineral content (sodium and/or potassium) of the feed is known.

If the content of sodium and/or potassium in the solid feed is varying over time, but the content is known, the variations can be compensated for in the estimation of the solid feed consumption. In countries such as Sweden, the potassium content in dry matter may vary heavily while the sodium content is normally low, and if such feed is used, the potassium content has to be tracked and correlated for, or potassium has to be added such that a constant level of potassium in the dry matter is maintained over time.

The processing device may be configured to estimate the absolute solid feed consumption of the animal, e.g. in kilograms of solid feed, based on the variation in forestomach temperature. For estimation of the solid feed consumption on an absolute level, accuracy is greatly improved if a calibration is made wherein variation in forestomach temperature of the animal is correlated with known amounts of consumed solid feed, e.g. as measured manually by means of weighing the solid feed given to the animal, if the solid feed contains amounts of sodium and/or potassium which are known and the temperature of the drinking water is also known.

By the above system, an accurate and precise approach is obtained for estimating dry matter intake on an animal individual level, which is also suitable to be implemented on full size commercial farms.

The value of the content of sodium and/or potassium in the solid feed can be entered manually into the system or measured automatically. The value does not have to be exact – it can be a simple estimation based on previous experience with a particular type of feed. The content of sodium and/or potassium in the solid feed may e.g. be between about 0.1 and 5 % by weight, preferably between about 0.5 and 5 % by weight, and most preferably between about 1 and 3 % by weight. Devices for automatically measuring the content of sodium and/or potassium in the solid feed may comprise NIR (near infrared spectroscopy) apparatuses or other kind of measuring apparatuses arranged at a system for preparing solid feed or at a system for feeding each animal with solid feed, such as e.g. at a feeding wagon.

The value of the temperature of the drinking water can be entered manually into the system or measured automatically. The value does not have to be exact – it can be a simple estimation based on previous experience at a particular farm. Water freshly pumped from a deep well usually has a certain temperature, while water left in a water trough quickly takes on the surrounding temperature. It may therefore not be necessary to measure the temperature in real time with a temperature sensor.

In one embodiment, the animal is a dairy animal and the processing device is configured to receive a value of the amount and/or fat content of milk drawn from the animal and to estimate the solid feed consumption also based on the received value of the amount and/or fat content of milk drawn from the animal. In particular, the water content of the milk produced by each animal may be measured and subtracted from the estimated water intake of the animal. The water intake from which the water in the milk produced is subtracted correlates more strongly to the amount of urine produced by the animal, and is thus better correlated to the dry matter intake.

In another embodiment, the processing device is configured to receive a value of the ambient temperature and/or humidity and to estimate the solid feed consumption also based on the received value of the ambient temperature and/or humidity. Temperature and/or humidity within normal ranges will only affect the water intake to a lesser degree. However, if the temperatures are very high and/or the humidity is very low, the water intake may increase for a given dry matter intake. Compensations in the estimation of the dry matter intake may be made if high temperatures and/or low humidity are prevailing.

As explained above, it is believed that it is the amount of urine produced by of an animal which is directly related to the mineral intake, and a measure of the amount of urine produced by of the animal would thus be the best parameter for estimating dry matter intake. However, the water intake of the animal, or the water intake from which the water in the milk produced by the animal is subtracted, is typically easier to estimate, and it can be seen as a measure of the urine produced by the animal, which in turn is a measure of, or at least correlated with, the dry matter intake (or the sodium and/or potassium intake).

Research has shown that there is a dramatic drop in reticulorumen temperature following water intake. Cornett et al. describe in *Impact of water intake on dairy cattle reticulorumen temperature* (J. Anim. Sci. Vol. 89, E-Suppl. 1/J. Dairy Sci. Vol. 94, E-Suppl. 1) that there is a direct relationship between water intake quantity and change in reticulorumen temperature. It is thus possible to estimate the water intake based on the variation in reticulorumen temperature, if account is taken of the temperature of the drinking water.

A second aspect refers to an arrangement for managing animals on a farm comprising the system for estimating the solid feed consumption of the first aspect, a system configured to prepare solid feed for the at least one animal based on the estimated solid feed consumption by that animal, and a feeding system configured to feed the animal with the solid feed prepared for that animal. The solid feed may be TMR (total mixed ration) or PMR (partly mixed ration) feed, forage such as silage or haylage, or concentrate. The composition, amount, and/or energy density of the solid feed may be controlled and/or adjusted based on the estimated solid feed consumption by the animal. Typically TMR and PMR feed rations are given to a group of animals, whereas the concentrate is given on an animal individual basis in fodder stations, in which the animals are identified. The composition, amount, and/or energy density of the concentrate can thus be controlled and/or adjusted for each animal individually based on the estimated solid feed consumption by that animal. Hereby, feed efficiency can be improved dynamically and continuously.

A third aspect refers to a method for estimating the solid feed consumption of at least one animal. According to the method, the forestomach temperature of the at least one animal is measured, solid feed containing a known content of sodium and/or potassium and drinking water of a known temperature are provided, and the solid feed consumption of each of the at least one animals is estimated based on the variation in forestomach temperature of the animal together with the content of sodium and/or potassium in the solid feed and the temperature of the drinking water. The forestomach is preferably the reticulum, and the forestomach temperature is preferably the reticulorumen temperature.

The content of sodium and/or potassium may be manually entered by the user or automatically measured by the system. The value does not have to be exact – it can be a simple estimation based on previous experience with a particular type of feed.

The solid feed may be provided with a content of sodium and/or potassium which is constant over time. Sodium and/or potassium may thus be added to the solid feed to provide a content of sodium and/or potassium which is constant over time.

The value of the temperature of the drinking water may be entered manually by the user or measured automatically. The value does not have to be exact – it can be a simple estimation based on previous experience at a particular farm.

A fourth aspect refers to a method of feeding animals on a farm comprising the method of the third aspect, wherein solid feed for each of the at least one animals is prepared based on the estimated solid feed consumption by that animal, and the at least one animal is fed with the solid feed prepared for that animal. The solid feed may be TMR or PMR feed or concentrate.

Other examples are given above with respect to the second aspect.

Advantages of the approaches disclosed above include the following:

Accurate and precise estimation of dry matter intake on an animal individual level is enabled.

Feed efficiency can be improved on an animal individual level and on a group level.

Detection of deviations and follow ups can be performed on an animal individual level. Also the severity of a disease can be assessed from the estimation of dry matter intake.

The approach can be used for genetic improvement.

The dry matter intake of all animals including dry and young animals can be estimated.

Groups of animals within a pen, such as e.g. first calvers, animals of same age, animals of same breed, etc., can be evaluated by the use of the approach.

The system is based on an assembly of existing devices.

No weighing of feed delivery and input of data of feed on a daily basis are required.

Further characteristics and advantages will be evident from the detailed description of embodiments given hereinafter, and the accompanying Figs. 1-5, which are given by way of illustration only.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates, schematically in a block diagram, an embodiment of an arrangement for managing animals on a farm.

Fig. 2 illustrates, schematically in a diagram, water intake versus potassium intake for a plurality of animals.

Fig. 3 illustrates, schematically in a diagram, produced urine versus potassium intake for an animal.

Fig. 4 illustrates, schematically in a diagram, water intake and produced urine versus potassium intake for an animal.

Fig. 5 illustrates, schematically in a flow scheme, an embodiment of a method for estimating the solid feed consumption of an animal.

DETAILED DESCRIPTION OF EMBODIMENTS

Fig. 1 illustrates, schematically in a block diagram, an embodiment of an arrangement 10 for managing animals on a farm. The arrangement 10 comprises a system 11 for estimating the solid feed consumption of at least one animal, a milking system 16 for milking the animals, a system 17 for measuring ambient temperature and/or humidity, a device 18 for either manually entering or automatically measuring the content of sodium and/or potassium in the solid feed, a device 19 for either manually entering or automatically measuring the temperature of the drinking water, a system 20 for preparing solid feed containing sodium and/or potassium for each animal, and a feeding system 21 for feeding each animal with solid feed. Here, it is assumed that the animals are dairy animals, but most of the approaches disclosed in this document are equally applicable to other kinds of animals.

The arrangement 10 may be a free stall or loose housing arrangement, in which animals can move, and the milking system 16 may be an automatic milking system provided with equipment for automatically measuring milk quantity and milk quality parameters. The system 17 for measuring ambient temperature and/or humidity may be based on any kind of known sensors.

The system 11 for estimating the solid feed consumption by animals on an animal individual level comprises, in the reticulorumen of each animal, a bolus 12, 13, 14. Examples of such boluses are described in US 2007/0088194, US 2012/0310054 and US 2013/0197323. Each bolus 12, 13, 14 comprises a transmitter 12a, 13a, 14a and a temperature sensor 12b, 13b, 14b for measuring the reticulorumen temperature. The transmitter 12a, 13a, 14a is used to transmit the values of the reticulorumen temperature to a processing device 15, which is configured to receive the measured reticulorumen temperatures from said at least one temperature sensor 12b, 13b, 14b. The processing device 15 is further configured to receive a value of the content of sodium and/or potassium in the solid feed and a value of the temperature of the drinking water and, for each of the animals, configured to estimate the solid feed consumption of that animal based on the reticulorumen temperature of the animal together with the received values of the content of sodium and/or potassium in the solid feed and the temperature of the drinking water. The processing device 15 may be a computer provided with suitable software.

Although the correlation with water intake is strongest for reticulorumen temperature variation, also the variation in any of the other forestomachs can be used. The bolus 12, 13, 14 could thus be placed in the rumen or the omasum instead of in the reticulum.

The value of the content of sodium and/or potassium in the solid feed may be entered manually by the user using device 18, which may e.g. be a computer keyboard. The value does not have to be exact – it can be a simple estimation based on previous experience with a particular type of feed. Alternatively, the value of the content of sodium and/or potassium in the solid feed may be measured automatically using a different device 18. Devices for automatically measuring the content of sodium and/or potassium in the solid feed may comprise NIR (near infrared spectroscopy) apparatuses or other kind of measuring apparatuses (not illustrated) arranged at the system 20 for preparing solid feed or at the system 21 for feeding each animal with solid feed.

The content of sodium and/or potassium in the solid feed may e.g. be between about 0.1 and 5 % by weight, preferably between about 0.5 and 5 % by weight, and most preferably between about 1 and 3 % by weight.

The value of the temperature of the drinking water may be entered manually by the user using device 19, which may e.g. be a computer keyboard. The value does not have to be exact – it can be a simple estimation based on previous experience at a particular farm. Alternatively, the value of the temperature of the drinking water may be measured automatically using a temperature sensor 19.

In one embodiment, the system 20 may be configured to prepare solid feed for an animal or a group of animals based on the estimated solid feed consumption by that animal or that group of animals. The solid feed may be TMR (total mixed ration) or PMR (partly mixed ration) feed, forage such as silage or haylage, or concentrate. The composition, amount, and/or energy density of the solid feed may be controlled and/or adjusted based on the estimated solid feed consumption by the animal or the group of animals. Typically TMR and PMR feed rations are given to a group of animals, whereas concentrate is given on an animal individual basis in fodder stations, in which the animals are identified. The composition, amount, and/or energy density of the concentrate can thus be controlled and/or adjusted for each animal individually based on the estimated solid feed consumption by that animal. The system 21 is configured to feed the animal or the group of animals with the prepared solid feed.

There is a direct relationship between water intake quantity and change in reticulorumen temperature. If the water temperature is known, the water intake quantity can be estimated based on the variation in reticulorumen temperature. For example, at a water temperature of 15°C, a drop in reticulorumen temperature of 4°C corresponds to a water intake of 11 liters, while a drop in reticulorumen temperature of 7°C corresponds to a water intake of 22 liters. At a water temperature of 2°C, a drop in reticulorumen temperature of 6°C corresponds to a water intake of 11 liters, while a drop in reticulorumen temperature of 9°C corresponds to a water intake of 22 liters.

The time taken to return to the normal reticulorumen temperature depends on both the water intake and the temperature of the water. For example, at a water temperature of 15°C, it takes about 35 minutes to return to the normal reticulorumen temperature after a water intake of 11 liters. This means that as long as 35 minutes or more have passed since the previous water intake, no corrections need to be made for any remaining temperature change in this situation. If less than 35 minutes have passed, however, corrections need to be made for accurate results.

Fig. 2 illustrates, schematically, in a diagram water intake in liters per day versus potassium intake in grams per day for a plurality of animals. It can be seen that the water intake is essentially proportional to the potassium intake via the feed. The slope and the offset at the y axis may be different for different animals, but the essentially linear relationship between water intake and potassium intake can be noted for each of the animals. By correlating estimated water intake for each animal with known amounts of consumed solid feed or known amounts of consumed sodium and/or potassium (e.g. as rations given by a farmer), e.g. at start up, the system can be calibrated and be configured to reliably estimate the solid feed consumption by each animal on an absolute level.

Thus, the water intake can be estimated based on the drop in reticulorumen temperature, and the estimated water intake can then be used to estimate the intake of sodium and/or potassium. If the content of sodium and/or potassium in the solid feed and the temperature of the drinking water is known, the solid feed consumption can thus be estimated based on the variation in reticulorumen temperature.

Alternatively, or additionally, the processing device 15 may be configured, for each of the animals, to receive a value of the amount and/or fat content of milk drawn from the animal and to estimate the solid feed consumption also based on the received value of the amount and/or fat content of milk drawn from the animal. Such values may be received from the milking system 16.

Yet alternatively, or additionally, the processing device 15 may be configured to receive a value of the ambient temperature and/or humidity and, for each of the animals, to estimate the solid feed consumption also based on the received value of the ambient temperature and/or humidity. Such value can be received from the system 17 for measuring ambient temperature and/or humidity.

Fig. 3 illustrates, schematically, in a diagram, produced urine in kilograms per day versus potassium intake in grams per day for an animal. It can be seen that the produced urine is essentially proportional to the potassium intake via the feed.

Fig. 4 illustrates, schematically, in a diagram water intake and produced urine in kilograms per day versus potassium intake in grams per day for an animal. It can be seen that the slope is similar, meaning that the sensitivities for the two parameters water intake and produced urine as measures of feed intake are similar.

Fig. 5 illustrates, schematically, in a flow scheme an embodiment of a method for estimating the solid feed consumption of at least one animal. According to the embodiment, solid feed containing a known content of sodium and/or potassium is, in a step 51, provided. Drinking water of a known temperature is, in a step 52, provided. For each animal, the forestomach temperature is, in a step 53, measured. Finally, the solid feed consumption of each of the at least one animals is, in a step 54, estimated based on the variation in forestomach temperature of said animal together with the content of sodium and/or potassium in the solid feed and the temperature of the drinking water. The forestomach is preferably the reticulum and the forestomach temperature is preferably the reticulorumen temperature.

The invention is not restricted to the embodiment described in the figures, but may be varied freely within the scope of the claims.

CLAIMS

1. A system (11) for estimating the solid feed consumption of at least one animal, wherein the solid feed comprises sodium and/or potassium, comprising at least one temperature sensor (12b, 13b, 14b) for measuring the forestomach temperature of said at least one animal, and a processing device (15) configured to receive the measured forestomach temperatures from said at least one temperature sensor (12b, 13b, 14b), wherein the processing device is further configured to:

- receive a value of the content of sodium and/or potassium in the solid feed;

- receive a value of the temperature of the drinking water; and

- estimate the solid feed consumption of each of the at least one animals based on the variation in forestomach temperature of said animal together with the received values of the content of sodium and/or potassium in the solid feed and of the temperature of the drinking water.

2. The system of claim 1 wherein the forestomach is the reticulum and the forestomach temperature is the reticulorumen temperature.

3. The system of claim 1 or 2 wherein the system comprises means (18) for automatically measuring the content of sodium and/or potassium in the solid feed.

4. The system of any of claims 1-3 wherein the content of sodium and/or potassium in the solid feed is between about 0.1 and 5 % by weight, preferably between about 0.5 and 5 % by weight, and most preferably between about 1 and 3 % by weight.

5. The system of any of claims 1-4 wherein the system comprises a temperature sensor (19) for automatically measuring the temperature of the drinking water.

6. The system of any of claims 1-5 wherein said animal is a dairy animal and the processing device is configured to receive a value of the amount and/or fat content of milk drawn from said animal and to estimate the solid feed consumption also based on the received value of the amount and/or fat content of milk drawn from said animal.

7. The system of any of claims 1-6 wherein the processing device is configured to receive a value of the ambient temperature and/or humidity and to estimate the solid

feed consumption also based on the received value of the ambient temperature and/or humidity.

8. An arrangement (10) for managing animals on a farm comprising the system (11) for estimating the solid feed consumption of at least one animal of any of claims 1-7, a system (20) configured to prepare solid feed for the at least one animal based on the estimated solid feed consumption by that animal, and a feeding system (21) configured to feed each of the at least one animals with the solid feed prepared for that animal.

9. A method for estimating the solid feed consumption of at least one animal, comprising the steps of:

- providing (51) solid feed containing a known content of sodium and/or potassium;

- providing (52) drinking water of a known temperature;

- measuring (53) the forestomach temperatures of each of the at least one animals; and

- estimating (54) the solid feed consumption of each of the at least one animals based on the variation in forestomach temperature of said animal together with the received values of the content of sodium and/or potassium in the solid feed and of the temperature of the drinking water.

10. The method of claim 9 wherein the forestomach is the reticulum and the forestomach temperature is the reticulorumen temperature.

11. The method of claim 9 or 10 wherein the content of sodium and/or potassium in the solid feed is automatically determined by the system.

12. The method of any of claims 9-11 wherein sodium and/or potassium are added to the solid feed to provide a content of sodium and/or potassium which is constant over time.

13. The method of 12 wherein sodium and/or potassium are/is added to obtain a content of sodium and/or potassium in the solid feed between about 0.1 and 5 % by weight, preferably between about 0.5 and 5 % by weight, and most preferably between about 1 and 3 % by weight.

14. The method of any of claims 9-13 wherein the temperature of the drinking water is automatically determined by the system.

15. The method of any of claims 9-14, wherein said at least one animal is a dairy animal, comprising the further steps of:

- measuring the amount and/or fat content of milk drawn from said animal; and

- estimating the solid feed consumption for said animal also based on the amount and/or fat content of milk drawn from said animal.

16. The method of any of claims 9-15 comprising the further steps of:

- determining the ambient temperature and/or humidity; and

- estimating the solid feed consumption also based on the value of the ambient temperature and/or humidity.

17. A method of feeding animals on a farm comprising the method for estimating the solid feed consumption of at least one animal of any of claims 9-16, wherein solid feed for each of the at least one animals is prepared based on the estimated solid feed consumption by that animal, and the at least one animal is fed with the solid feed prepared for that animal.

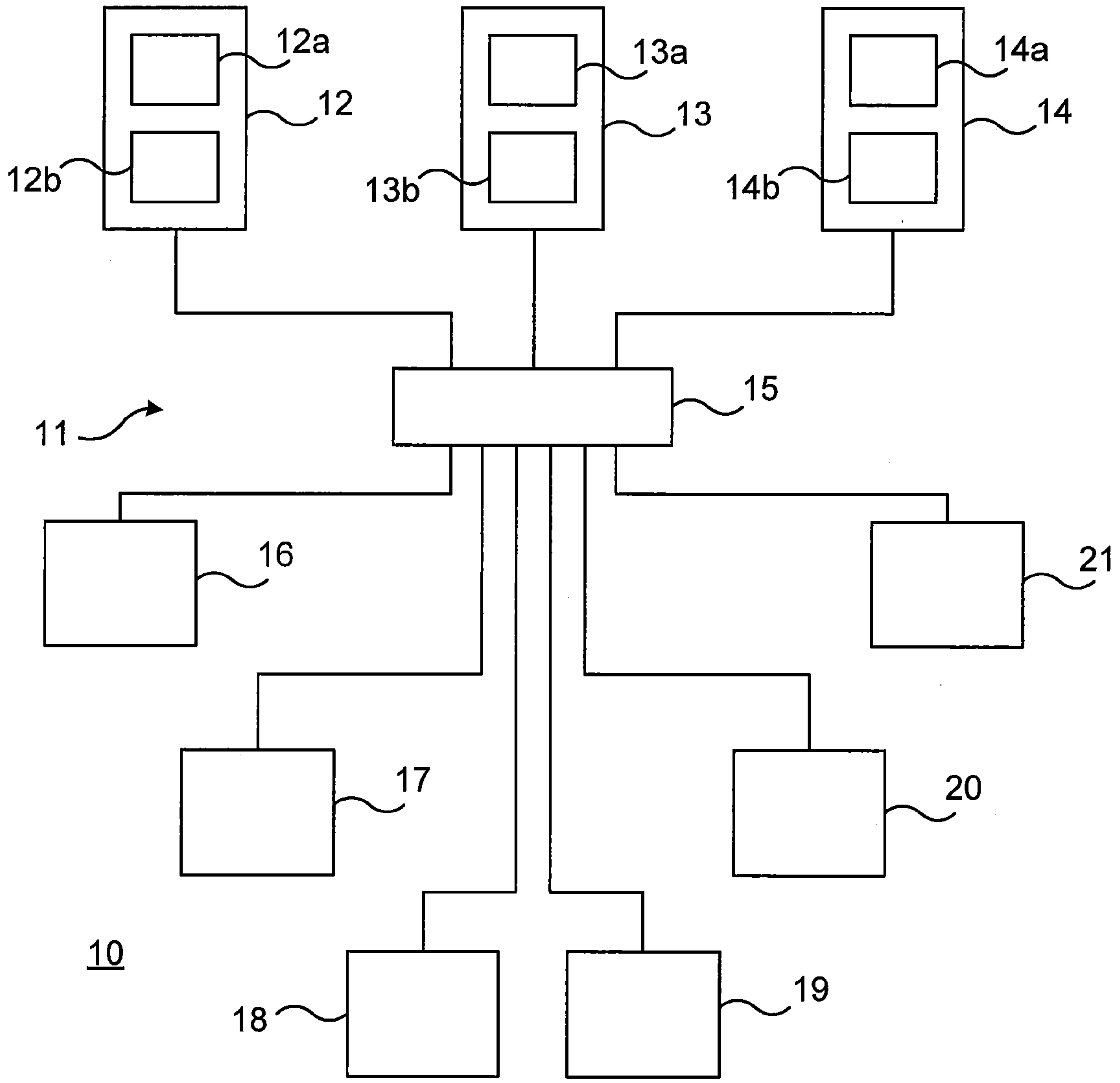

Fig. 1

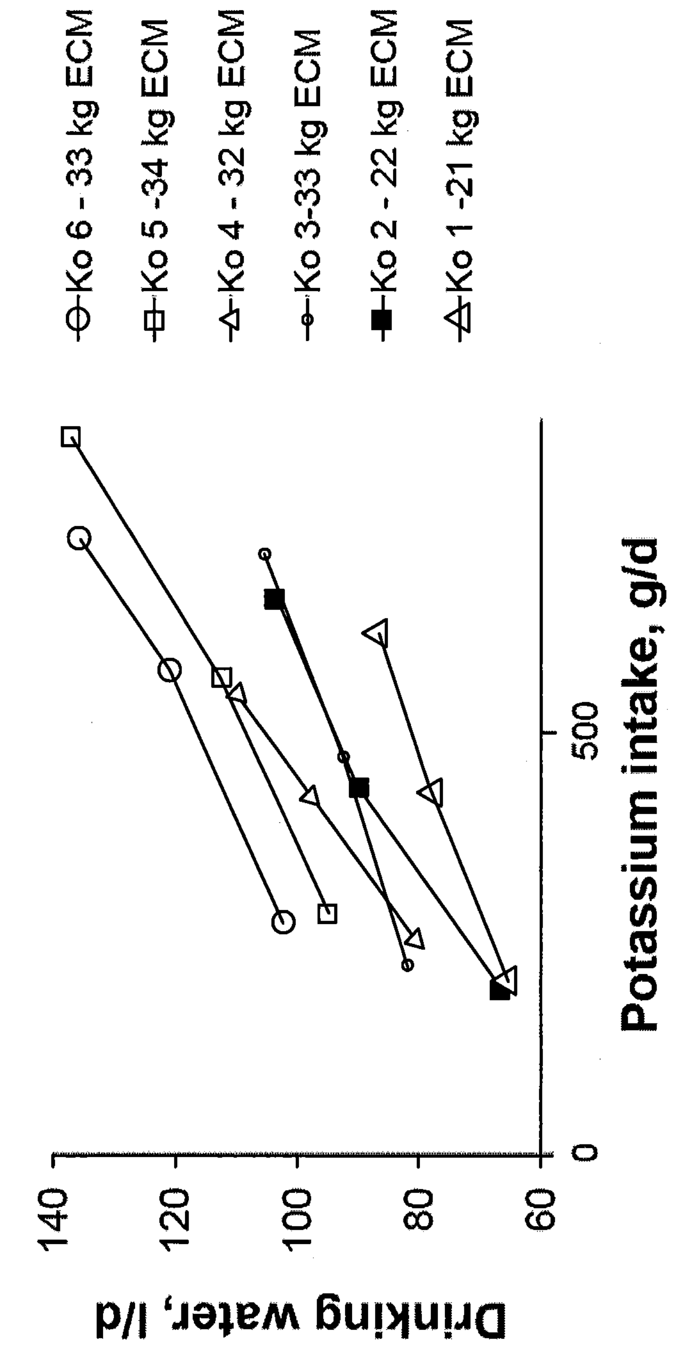
Ko 6 - 33 kg ECM
Ko 5 -34 kg ECM
Ko 4 - 32 kg ECM
Ko 3-33 kg ECM
Ko 2 - 22 kg ECM
Ko 1 -21 kg ECM
Drinking water, l/d
140
120
100
80
60
0
500
Potassium intake, g/d

Fig. 2

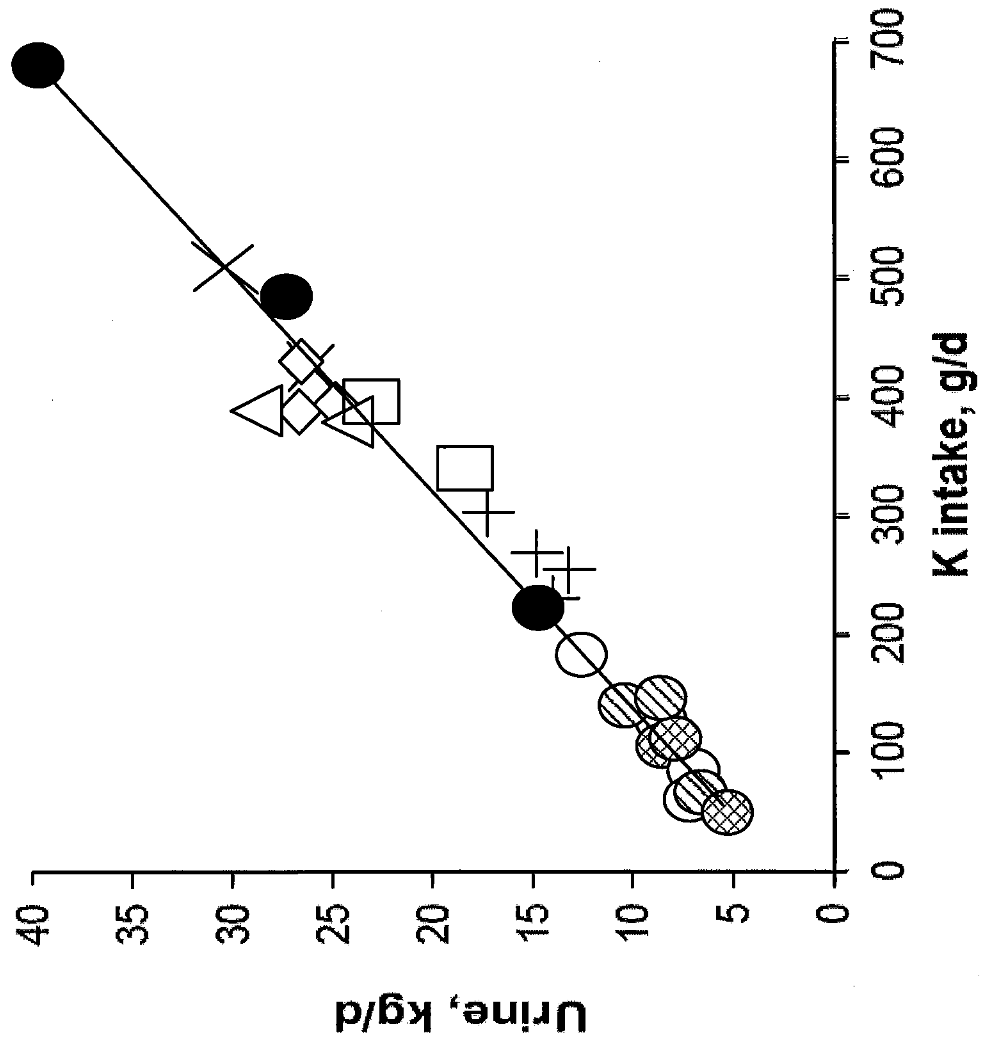
Urine, kg/d
40
35
30
25
20
15
10
5
0
K intake, g/d
0
100
200
300
400
500
600
700

Fig. 3

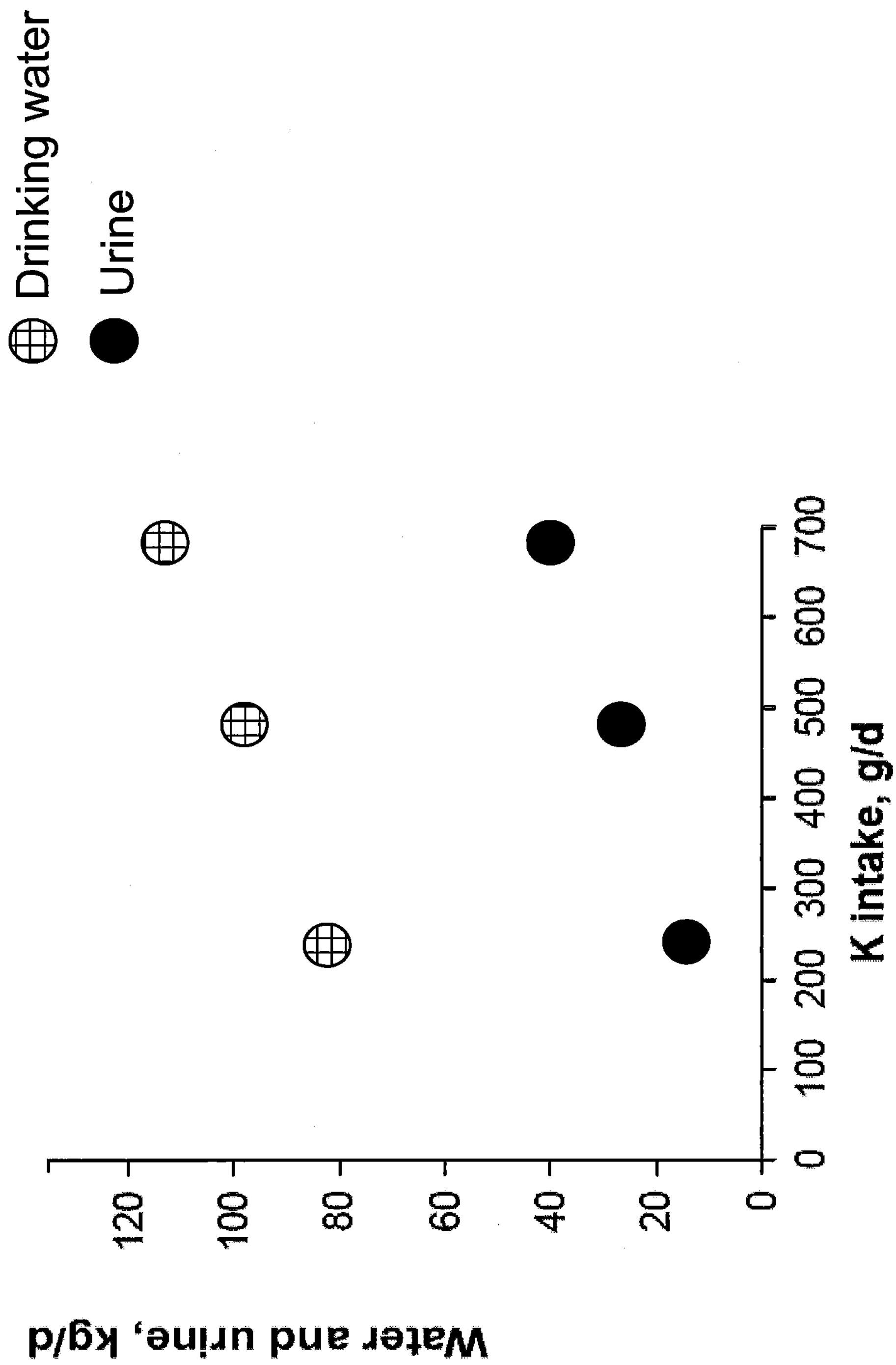
Drinking water
Urine
Water and urine, kg/d
0
20
40
60
80
100
120
K intake, g/d
0
100
200
300
400
500
600
700

Fig. 4

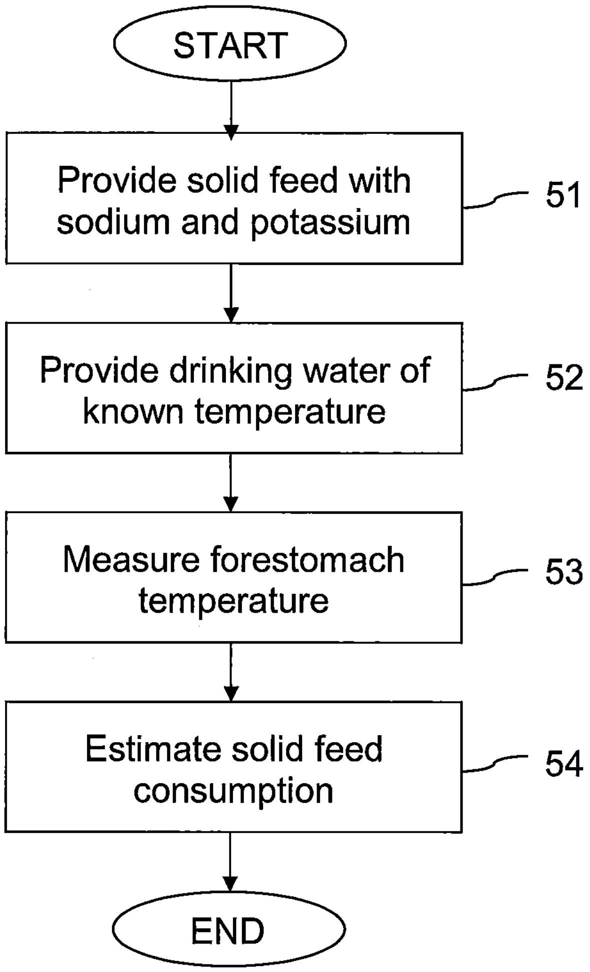
START
Provide solid feed with sodium and potassium
51
Provide drinking water of known temperature
52
Measure forestomach temperature
53
Estimate solid feed consumption
54
END

Fig. 5