FEED-A-GENE

Adapting the feed, the animal and the feeding techniques to improve the efficiency and sustainability of monogastric livestock production systems

Deliverable D2.3

Traits related to the individual feed intake in group-housed broilers and rabbits, and the capacity of broilers to optimise their diet and nutrient intake related to feed efficiency

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1. Summary

Objectives

Feed cost is the main production cost in poultry and rabbits, and represents 50 to 70% of the total production cost. Consequently, feed efficiency is the most important selection criterion in these species. For meat-type producing animals, feed efficiency is defined as the ratio between weight gain to feed intake during a given period. Weight gain is relatively easy to obtain at the individual scale, although it is labour intensive. On the opposite, feed intake measurements in individual animals are more difficult to obtain. In chickens, to measure feed intake, birds are housed in individual cages and the feeder has to be weighed at regular intervals. This method has several drawbacks:

- Animals are housed individually whereas they are usually reared in groups
- Animals are housed in cages whereas they are usually reared on the floor
- The measurement is available only for longer periods, usually one measurement per week or every two weeks. This provides a very limited indication of the changes in feed intake, considering that a broiler production cycle is lasting only 5 weeks.

The objective of this deliverable is to use automatic feeding stations to obtain individual data of feed intake in group-housed animals, and that are reared in conditions as close as possible to production conditions (e.g., on the floor for chickens, in collective cages for rabbits). Moreover, these feeding stations allow for the continuous collection of data of feed intake and to establish the dynamics of feed intake within a day, and all along the production cycle.

These new traits have been correlated to feed efficiency to propose new traits that can be used for both nutrition and genetics studies of feed efficiency in poultry and rabbits.

Rationale:

Feeding stations are developed for individual recording of feed intake in both rabbits and chickens. Animals are identified electronically using RFID tags that are detected automatically by the feeding station when animals enter the feeding station.

In chickens, animals are detected and identified by an antenna placed on the front access of the feeder. As animals climb on a plateau mounted on a scale and they are weighed at each visit. Feed intake is calculated at each visit as the difference between feeder weight at the beginning and at the end of the visit. To check whether feed intake patterns were generic or specific for a given type of production, the station was tested using rapidly growing broilers and using Label Rouge chickens with a lower growth rate, and with different types of diets. Consistency of visits collected by the feeding station and true visits were assessed by video recording.

In rabbits, measurements are done in collective cages with 4 to 7 rabbits. A circular antenna is placed at the entrance of a corridor giving access to the feeder. Feed intake is calculated at each visit as the difference between feed weight in the feeder at arrival and at departure of the rabbit. Experiments to determine the ideal size of the group of rabbits, to test the reliability of the measurements, and to estimate the effect of the feeding station on growth performance of

rabbits have been carried out. Feed intake, feeding behaviour, and growth traits have been compared with different numbers of rabbits per cage and between different types of feeders.

Teams involved:

INRA: poultry experiments
IRTA: rabbit experiments
UNEW: behavioural assessment in poultry experiment

Species and production systems considered:

Poultry and rabbits were considered in this deliverable. Applicability of the results is worldwide.

2. Introduction

Feed costs represent the main part of production costs in many species, including poultry (50-70% of total cost depending on the production type) and rabbits. The efficiency to use feed is thus the first criterion of the economic pillar of sustainability. This is also an indicator of the environmental impact of production as it is highly correlated to nutrient excretion (de Verdal *et al*., 2013). In growing animals used for meat production, this criterion is often assessed through the feed conversion ratio, which is the ratio of feed intake to growth rate during a given period. Measuring animal body weight is relatively easy, but can be laborious. On the opposite, measuring feed intake of individual animals is much more difficult.

Until recently, to measure feed intake in chickens, animals were reared in individual cages equipped with individual feeders, separated from the other animals (Figure 1). Animals and feeders were weighed at 1 or 2-week intervals, because feed intake measurements are not considered reliable when measured for shorter intervals. This method has several drawbacks. First, animals are reared in artificial conditions that are different from production conditions (isolated vs in groups, in cages vs on the floor), which can affect feed intake and feeding behaviour. Second, it has a negative impact on animal welfare due to the long period of cage-rearing. Third, it gives only very partial information on feed intake, as a maximum of one value of cumulative feed intake in a week per bird is obtained. Therefore, the dynamics of feed intake during the production cycle and within a day were not available.

Figure 1. Individual feed intake measurement in cages.

The partners have developed feeding stations, which have been developed further in the Feed-a-Gene project to solve these problems. For chickens, birds are equipped with a RFID chip (134 or 125 KHz) on the neck, which allows detection of the bird by an antenna placed on the top of the access to feed (Figure 2). Each feeder access has its own scale to measure remaining feed in the feeder. When a bird wants to eat, it climbs on a plateau mounted on a scale and the bird is then weighed. Both feed intake and the weight of the bird can thus be obtained at the individual level and in production conditions, without modification of the natural behavior of the animal.

Figure 2. Individual feed intake measurement using the feeding station in birds raised on the floor.

For rabbits, animals are equipped with a RFID ear tag at 125 KHz and are detected by a circular antenna placed at the entrance of a corridor of access to the feeder (Figure 3). A photoelectric cell is used to detect the presence of animals in the feeder. Feeder weight is recorded every second. A complete description of this system is provided in deliverable D2.2.

Figure 3. Feeding stations used in rabbits.

3. Results

3.1 Poultry data

To determine which criteria could be used to describe feed intake and feeding behaviour in chickens, a series of four experiments were performed.

- <u>Experiment 1</u> (March-April 2017): 80 Cobb500 birds were reared during 5 weeks, using a standard diet, to test how fast birds get used to the feeding station and to test the reliability of the body weight data obtained from the station.
- <u>Experiment 2</u> (September-November 2018): 80 medium growing broilers were reared during 7 weeks, to define the algorithm of calculation of feed intake and to test reliability of feed intake data.

- Experiment 3 (May-June 2018): 80 Cobb500 birds were reared during 5 weeks, using a standard diet to validate and to adapt the algorithm used to calculate feed intake.
- Experiment 4 (September 2018-March 2019): 80 Label Rouge birds and 80 Cobb500 birds were fed either a classical corn-soybean diet or an alternative diet including local feedstuffs and by-products of cereals. The aim is to compare feed intake, feeding behaviour, and feed efficiency data depending on genotype and diet.

3.1.1. System reliability

To test the familiarization of the birds to the station, the proportion of animals that were detected during the first days of the experiment was calculated. It appears that animals get used to the feeding station very fast. All birds started to use the feeding station in less than 3 days after their arrival (see Figure 3 for an example with Cobb500 birds). After this time, all birds are detected every day by the feeding station.

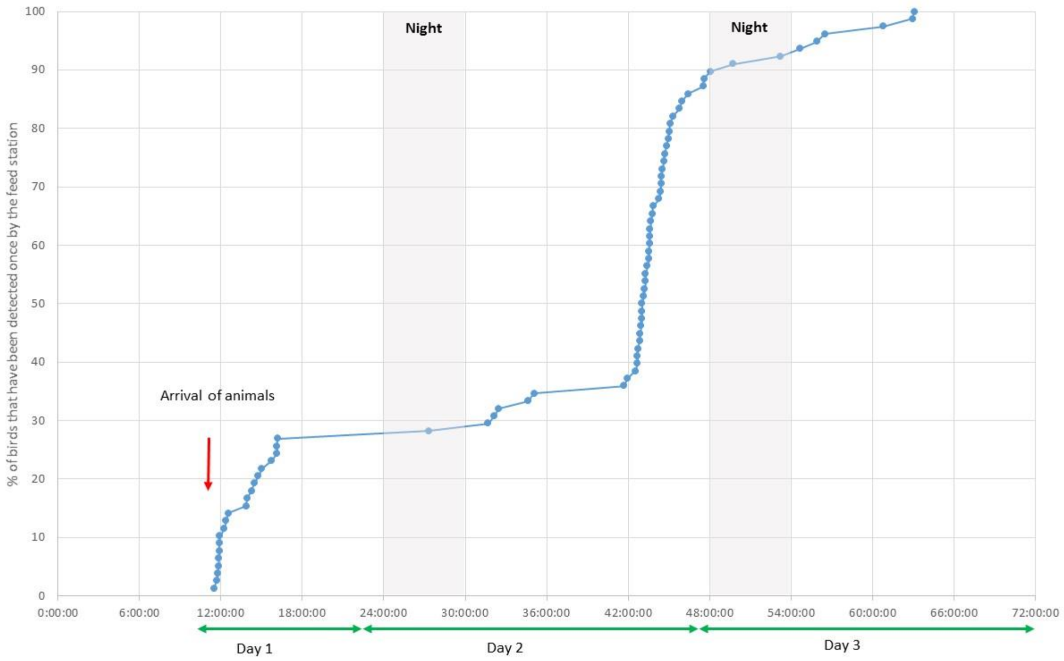


Figure 4. Time at which birds are detected for the first time by the feeding station.

Growth of birds was not affected by the feeding station, and the recorded weights were slightly above the reference growth curve for Cobb500 chickens. The difference between manually and automatically recorded weights was low (2%, Figure 5).

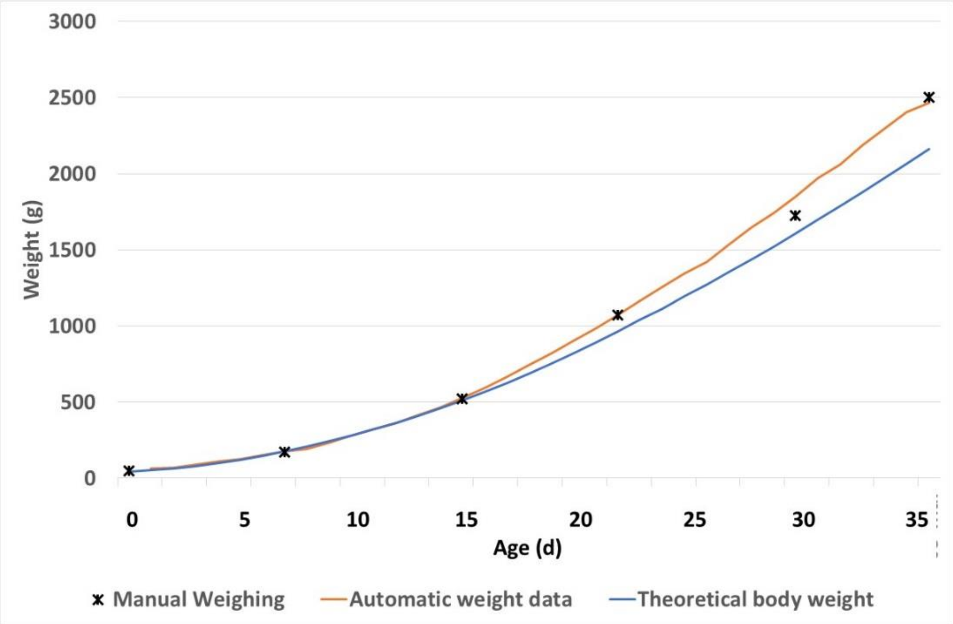


Figure 5. Growth curve of Cobb500 birds using the feeding station (orange: automatic records, blue: theoretical growth curve; black: manually recorded weights).

To ensure that animals were well detected by the feeding station, we compared visits detected by the feeding station and visits detected by video recording. In an experiment performed on medium growing broilers, we recorded during 8 days a total of 1096 visits by video analysis. Among these visits, 95% were detected by the feeding station. The 5% missed visits included one-half of truly missed visits and one-half of very short visits (of less than 10 seconds) that could not be associated with feed intake (Kefi, 2018).

An algorithm was developed to calculate feed intake based on data collected on 80 Cobb birds during one day. It represented 593 feeding visits. Cook's distance (Cook, 1977) was used to remove feed weight data that had a large influence on the mean weight between two visits. After correction to zero of negative feed intake values (mainly due to very short visits leading to high fluctuations of the scales), the mean absolute value of the difference between calculated and measured feed intake was 2.8%.

3.1.2. Feed intake data in chickens

Based on data collected during the experiments, we combined second-by-second data of feed weight for each access to the feeding station and electronic chip detection at each feeding visit to identify new feed intake traits. The first step is to define the limits of a visit. Based on video observation and on data collected by the feeding station, a feeding visit is defined as:

- starting when a new electronic chip is detected,
- ending when the same chip is no longer detected within 2 minutes between two consecutive readings of the same chip. The series of reading has to be continuous, i.e. no other chip is read during the sequence,
- extended before the first reading or after the last reading of the chip when variation of feed weights in the access indicates that animal has not been detected immediately or was no longer detected before departure.

When two visits are very close, the time can be insufficient for the feed scale to ensure a stable reading. In that case, the two successive visits were grouped and the total duration of the feeding block (D_B) was calculated as the sum of duration of both visits (D_V). Feed intake of each visit (FI_V) is calculated as a proportion of feed intake of the block (FI_B):

$$FI_V = \frac{D_V \times FI_B}{D_B}$$

Once the amount of feed is calculated for each visit, we are able to determine new feed intake traits:

- number of visits per day
- duration of each visit
- dynamics of the visits during the day (e.g., many visits throughout the day, visits at key moments during the day)
- feed intake at each visit
- total feed intake during the day
- feed intake rate (g/min)
- number of visits to different feeder accesses (1 to 8 per feeding station). With several feeding stations, we will also be able to see if different stations are visited by a given animal, giving information on its preferred feeding spots.

Some elements of social behaviour could also be obtained from the elementary data of the feeding stations. For example, social groups could be identified if several animals are recorded frequently at the same time. Moreover, if a given animal is frequently read in the middle of feeding sequences of many other animals, it could be a dominant animal disturbing the access to the feed of dominated animals.

Below is an example of these new feed intake traits during one day on several medium-growing broilers. The daily duration of feed intake and the duration of each visit is highly variable between animals, as well as the feed intake rate, but the total daily feed intake is similar. Within a day, bird 23 and bird 243 have frequent and short meals of 20-40 seconds, whereas bird 115 and bird 248 have both short and long meals (Table 1).

Table 1. Feed intake and feeding behaviour data in four medium-growing broilers.

Bird	N° of visits	Mean duration (seconds)	Min-Max Duration (seconds)	Total Duration	Intake rate (g/min)	Total feed intake (g/d)
23	47	34.9	0-156	27 min 21 sec	2.17	53.6
115	31	86.8	2-203	44 min 51 sec	1.11	50.7
243	32	63.4	0-158	33 min 50 sec	1.80	54.3
248	48	42.9	0-231	34 min 20 s	2.44	53.5

Figure 6 is an example of dynamics of feed intake obtained during the same period (a dash represents a period of feeding). This now needs to be confirmed on a larger number of animals.

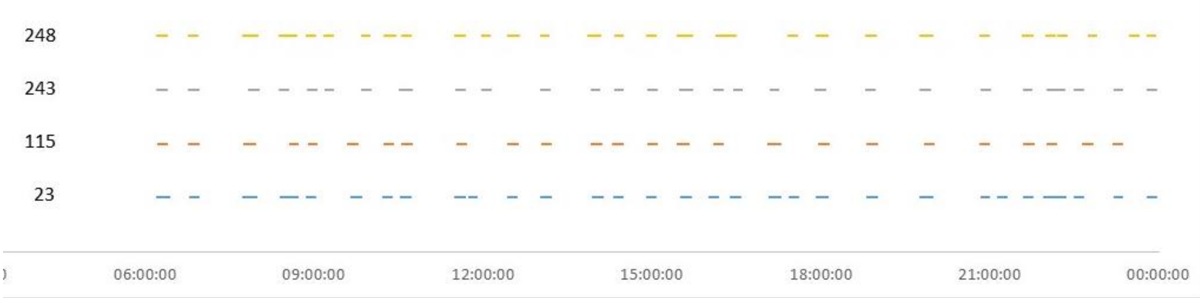


Figure 6. Dynamics of feed intake depending on bird.

Another element of feeding behaviour that we calculated was the preference of birds for a given access of the station. In Table 2, we can see that bird 243 does not use the eight accesses to the feeder independently, whereas bird 248 does not show any preference.

Table 2. Repartition of visits to the different accesses depending on the animal.

Bird	Access								P (χ^2)
	1	2	3	4	5	6	7	8	
23	10.6	12.8	10.6	10.6	12.8	19.1	0.0	23.4	0.09
115	6.5	22.6	9.7	6.5	29.0	6.5	9.7	9.7	0.09
243	21.9	18.8	25.0	12.5	0.0	12.5	6.3	3.1	0.04
248	14.6	12.5	14.6	14.6	18.8	12.5	6.3	6.3	0.60

3.1.3. Effect of diet and genotype on feed intake data.

Figure 7 shows the daily feed intake per chicken for the whole experiment for alternative (black curves) and classical (blue curves) diets. Classical diets are based on corn and soybean whereas alternative diets include less soybean meal (to reduce imports and increase protein autonomy) and more cereal by-products (to limit competition between human and animals). Figure 8 shows the body weights for the same birds. Solid lines represent data collected automatically by the feeding station and dashed lines represent data coming from manual weighing. In both cases, automatic and manual data are relatively close.

Animals consumed 12% more feed and were 3% heavier with the alternative diet than with the classical diet. Analysis of other feed efficiency and feeding behaviour traits is on-going. Data on standard chickens will be collected in February-March 2019.

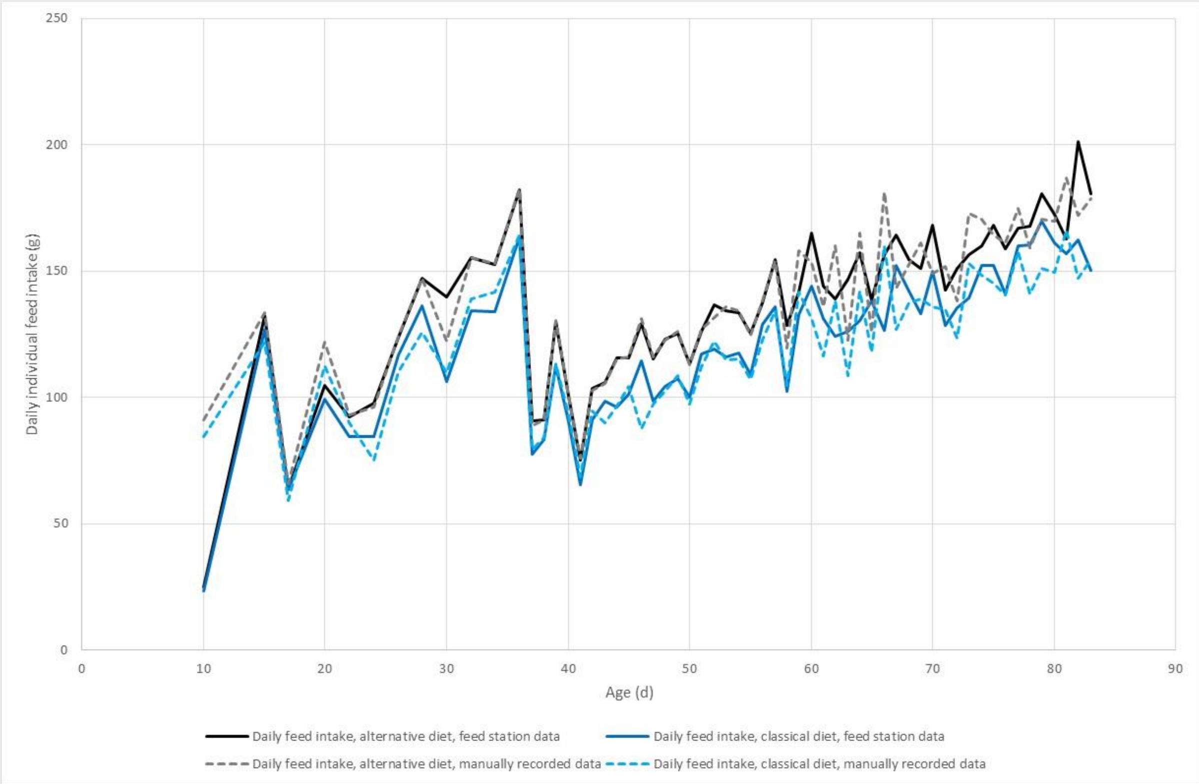


Figure 7. Comparison of daily feed intake per bird as recorded by the feeding station or by manual weighing, for a classical or an alternative diet.

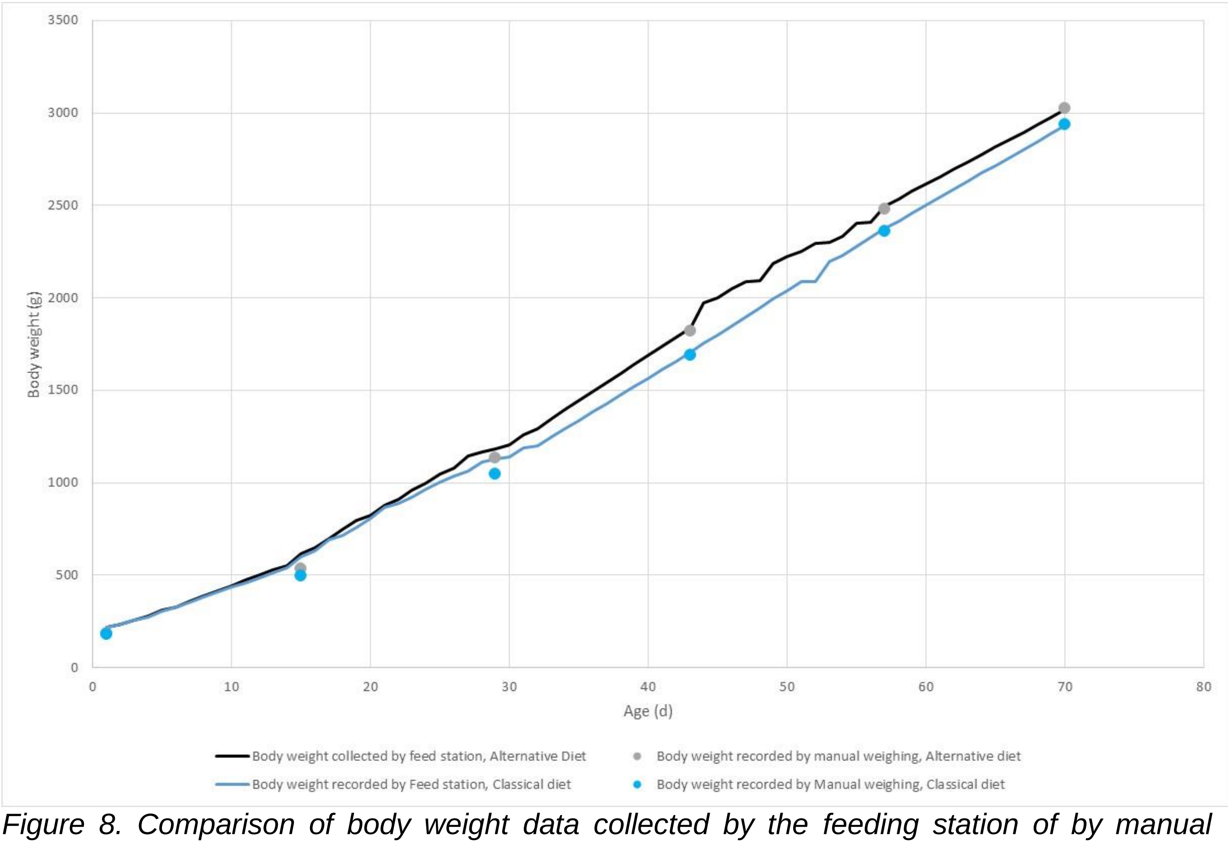


Figure 8. Comparison of body weight data collected by the feeding station of by manual weighing of birds, for a classical or an alternative diet.

3.2 Rabbit data

In rabbits, a feeding device has been developed as described in deliverable D2.2 of the Feed-a-Gene project. Data have been collected at each visit and sent to a database. Daily information for each individual animal is then obtained and, at the end of the fattening period, individual information for the whole fattening period is saved in the database. Depending on the objective of the study, information can be retrieved at the level of the visit, per day, or for the whole fattening period.

In Figure 9, a timeline of the different experiments conducted during the project is given. All the activities conducted since the full availability of the device in the farm are indicated:

- Experiments indicated in yellow: batches used for the selection experiment (task 5.5).
- Experiments indicated in green: experimental batches. In some of these batches, feed intake at the cage level was recorded manually and compared with data provided by the electronic feeders.
- Experiments indicated in red: batches in which feed intake was available only at the cage level.

Information recorded during the first five batches of 2018 have been communicated as an oral presentation at the 2018 Symposium of the Spanish Association of Rabbit Production (ASESCU) meeting (Sanchez *et al*., 2018).

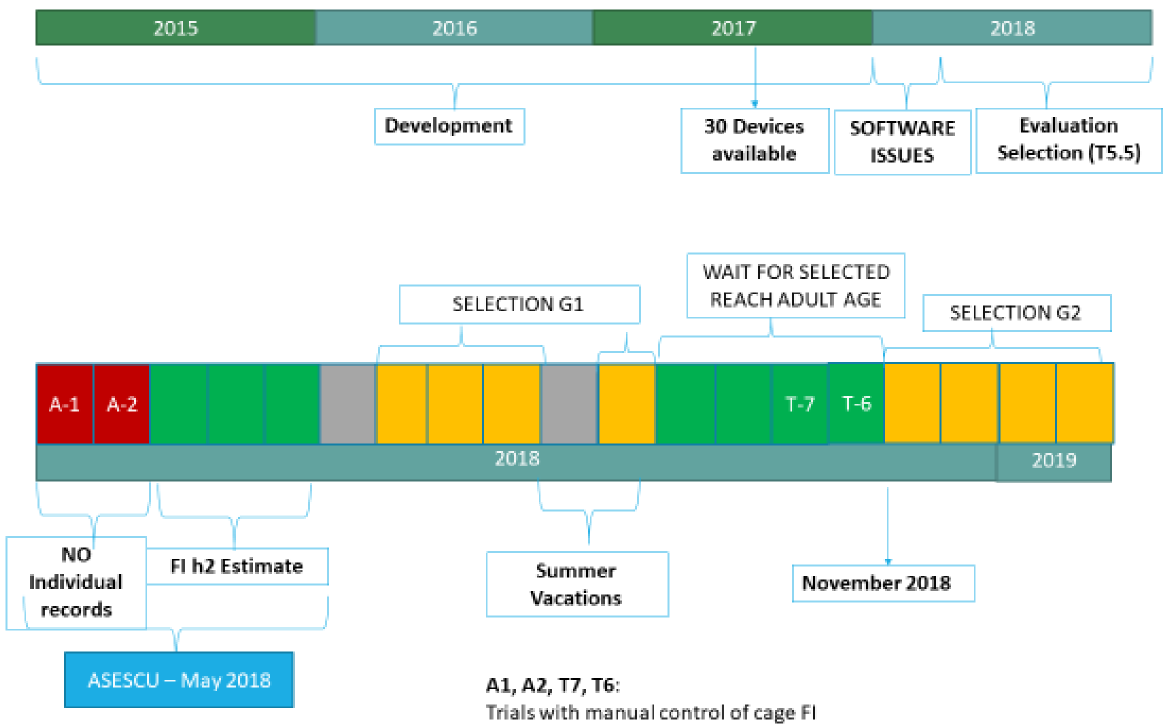


Figure 9. Timeline of the development of the electronic rabbit feeder and experimental trials conducted during the project.

3.2.1. Growth and feed intake assessment using electronic feeders

The objectives are:

- To assess the influence of the electronic feeder on feed intake and growth.
- To explore the consequences of increasing the number of animals per cage equipped with an electronic feeder on growth and feed intake of the rabbits.

To accomplish these objectives, information and results from different experimental trials have been integrated. A brief description of the different experimental trials is given before reporting the results. This is done separately for each trial and overall conclusions will be given.

Trials A1 and A2

They are replicates of the same design. Within each trial, five different experimental treatments were compared:

- ***C-integrated*** (C stands for commercial): the feeders are integrated in the cage and connected to the automatic feed provision system (Figure 10A). With these feeders, it is not possible to measure feed intake. Between five and six animals are housed in each cage of this type.
- ***C-not-integrated*** (C stands for commercial): the commercial feeders are not integrated in the cage (Figure 10B). As they are removable, it is possible to weigh leftovers of feed and cage feed intake can be measured. Between five and six animals are housed per cage.
- **E-5**, **E-6,** and **E-7** (E stands for electronic): three prototypes of electronic feeders were used. In trials A1 and A2, individual feed intake information recorded by the feeders was not reliable and not used for these trials. However, cage feed intake was recorded manually, by measuring the amount of feed provided to the electronic feeder.

Least-square means for the different treatments of trials A1 and A2 are given in Table 3. Using the electronic feeder devices penalised growth as growth rate was equal or higher in the commercial feeders than in those equipped with electronic feeders. This could be associated to the size of the group. In trial A1, the growth rate decreased with the number of animals per cage in cages with electronic feeders. However, in trial A2 the opposite was observed. Although not significant, important differences (up to 47 g/d) were observed for average feed intake of animals in cage "C-not integrated" compared to those in cages with electronic feeders.

A) C-integrated

B) C-not-integrated

Figure 10. – Commercial feeders used in the different trials: A) ***C-integrated****: the feeder is integrated in the cage and with the automatic feed provision system. B)* ***C-not-integrated****: the feeder is not integrated in the cage; it can be removed and allows manual recording of cage feed intake.*

Table 3. Least-square means (+ SE) for average daily gain and average daily intake for the different experimental groups in trials A1 and A2.

Feeder type	Animals per cage	Body weight gain (g/d)		Feed intake (g/d)	
		A1	A2	A1	A2
C-not-integrated	4-6	48.4 (0.96)[a]	50.7 (1.02)[ab]	191 (15.8)[a]	175 (15.8)[a]
C-integrated	5-6	50.8 (0.63)[a]	51.1 (0.68)[a]		
E-5	5	48.4 (1.25)[a]	45.7 (1.17)[c]	166 (19.8)[a]	131 (18.5)[a]
E-6	6	44.3 (1.12)[ab]	46.1 (1.13)[c]	156 (18.5)[a]	128 (19.8)[a]
E-7	7	43.3 (1.11)[b]	47.3 (1.12)[ab]	156 (19.8)[a]	129 (19.8)[a]

Different superscripts within column indicate that means are statistically different (P<0.05).

Trials T7 and T6

These two trials correspond to batches from the selection experiment conducted in task 5.5. The numbers behind T in the name of the trials stand for the number of animals raised per cage equipped with the electronic feeder (7 and 6, respectively). Within T6 and T7, three lines selected on different traits were compared. The characteristics of the three genetic lines under selection are the following:

- **RFI**: Selected for individual residual feed intake when feed is provided *ad libitum*.
- **ADGR**: Selected for growth corrected for feed intake when feed supply is restricted. Restriction is done by limiting access to the feeder device to 12 h/d.
- **GRP**: Selected for cage residual feed intake. The selection unit is the group (4 animals). In this line, feed intake is measured using the C-not-integrated system (Figure 10B).

For the RFI and ADGR selection trials, individual feed intake was measured by the electronic feeders, and cage feed intake was also recorded manually. Each line has a control group since part of the animals from each line were raised using the *C-integrated* system (Figure 10B), without measurement of feed intake.

Table 4. Mean values for average daily gain (ADG), individual feed intake, and cage feed intake recorded (ADFI) in trials T6 and T7 with electronic feeders.

Treatment group	Feeder type	T7 (7 rabbits per cage)			T6 (6 rabbits per cage)		
		ADG (g/d)	Indiv. ADFI (g/d)	Cage ADFI (g/d)	ADG (g/d)	Indiv. ADFI (g/d)	Cage ADFI (g/d)
RFI-control*	C-integrated	59.6			51.7		
RFI	Electronic	46.6	142	178	47.0	151	166
ADGR-control*	C-integrated	59.0			48.2		
ADGR	Electronic	34.1	115	137	34.1	117	133
GRP-control*	C-integrated	59.4			51.9		
GRP**	C-not-integrated	64.8		212	53.2		206

** Control groups were formed by 5-6 rabbits per group.*
*** In treatment GRP 4 rabbits, per cage were raised.*

As observed in trials A1 and A2, the use of the electronic feeder penalised the growth of the animals. The ADG was consistently lower with the electronic feeder than in the control group for the lines selected for RFI and GRP. The contrast between feeders for the ADGR line is not informative since the control group is under *ad libitum* feeding while the animals with the electronic feeder are fed restrictedly. In the RFI and ADGR lines, growth was similar for groups of six or seven animals when using electronic feeders.
Feed intake of *ad libitum* fed animals was 16-20% lower in the RFI line with the electronic feeder than in GRP line with commercial feeders, which is similar to the result observed in trials A1/A2.
Individual feed intake obtained with the electronic feeder was 10-20% lower than records computed from cage feed intake measurements. Part of this difference can be explained by the raw data treatment from the electronic feeders are treated. The algorithm discards some visits considered as false visits. In some cases, these visits are real, which leads to an underestimation of feed intake.

<u>Remarks:</u>
- The electronic feeders penalize growth; this is probably associated with the fact that animals feel uncomfortable accessing the feeder through a tunnel. Another possibility could be that dominant animals occupy the tunnel not allowing others to access the feeder.
- The lower growth rate observed with electronic feeders is associated with a lower feed intake.
- Feed intake recorded by the electronic feeders is lower than the actual feed intake.

- Further research is still needed to :
  - Improve the software of data treatment to reduce the bias in feed intake estimation.
  - Propose alternative ways to use the electronic feeder aiming to minimize the reduction in growth rate when using this device. One possibility is to combine two cages, offering to each animal access to two feeders instead of one. We believe that this could partially avoid the problems associated to several individuals occupying a feeder for a very long time.

3.2.2. Feeding behaviour traits

The description of feeding behaviour data recorded by the electronic feeder is based on records obtained in trials T6 and T7, in cages equipped with the electronic feeders, i.e., with animals from lines RFI (fed *ad libitum*) and ADGR (restricted to 12 h/d of feeding).

Feeding behaviour traits were measured at two different levels:

- Cage level: hourly feed intake patterns within a day
- Individual level: the variation across animals was aggregated for the whole fattening period and their correlation with feed efficiency traits was calculated.

3.2.2.1. Cage level

At the cage level, the hourly pattern of feed intake has been compared between *ad libitum* (line RFI) and feed-restricted animals (line ADGR). Figures 10 and 11 show these patterns in T7 (seven animals per cage) and T6 (six animals per cage), respectively.
As expected for the ADGR line, there was an important reduction in the feed intake and occupation time during the period during which no feed was provided (i.e., from 6:00 to 18:00). During this period, feed intake was not exactly zero because in certain feeders, feed was distributed just before 6:00, allowing a feed provision that can last for up to 4-5 hours. The area under the curve shows that the total feed intake for the ADGR line is about 80% of that of the RFI line. However, during the period of access to feed, feeding rate is about 2.5 g/min in the ADGR line and only 1.75 g/min in the RFI line. The number of visits of feed-restricted animals is also higher than in *ad libitum* fed animals (50 vs 25 visits per hour). Moreover, there is less variability in feed intake and occupation time across days and cages in the RFI line (points in a given hour). During feeding periods, the difference in feeder occupation time between the RFI and ADGR lines is low. It seems a bit higher in cages with *ad libitum* feeding (60%) than in cages with feed restriction (50%). Under feed restriction, there are more visits and thus more spaces between visits that are counted as non-occupied time. This may result in competition between animals to access the feeder. Cage mates often drive the feeding animal out of the feeder. The similar occupation time between the RFI and ADGR lines could be an indication that seven animals in a cage is too many relative to the capacity of one feeder. A too large number of animals in a cage with individual feeder could create an undesired feed restriction. The fact that occupation time is constant throughout the day may support this hypothesis, which is reinforced by the observation that with six animals per cage, the occupation time throughout the day is not constant in *ad libitum* fed animals (Figure 11). In that case, although the number of visits per hour remains more or less constant (25-30), the feeding rate is reduced to 1.25 g/min.

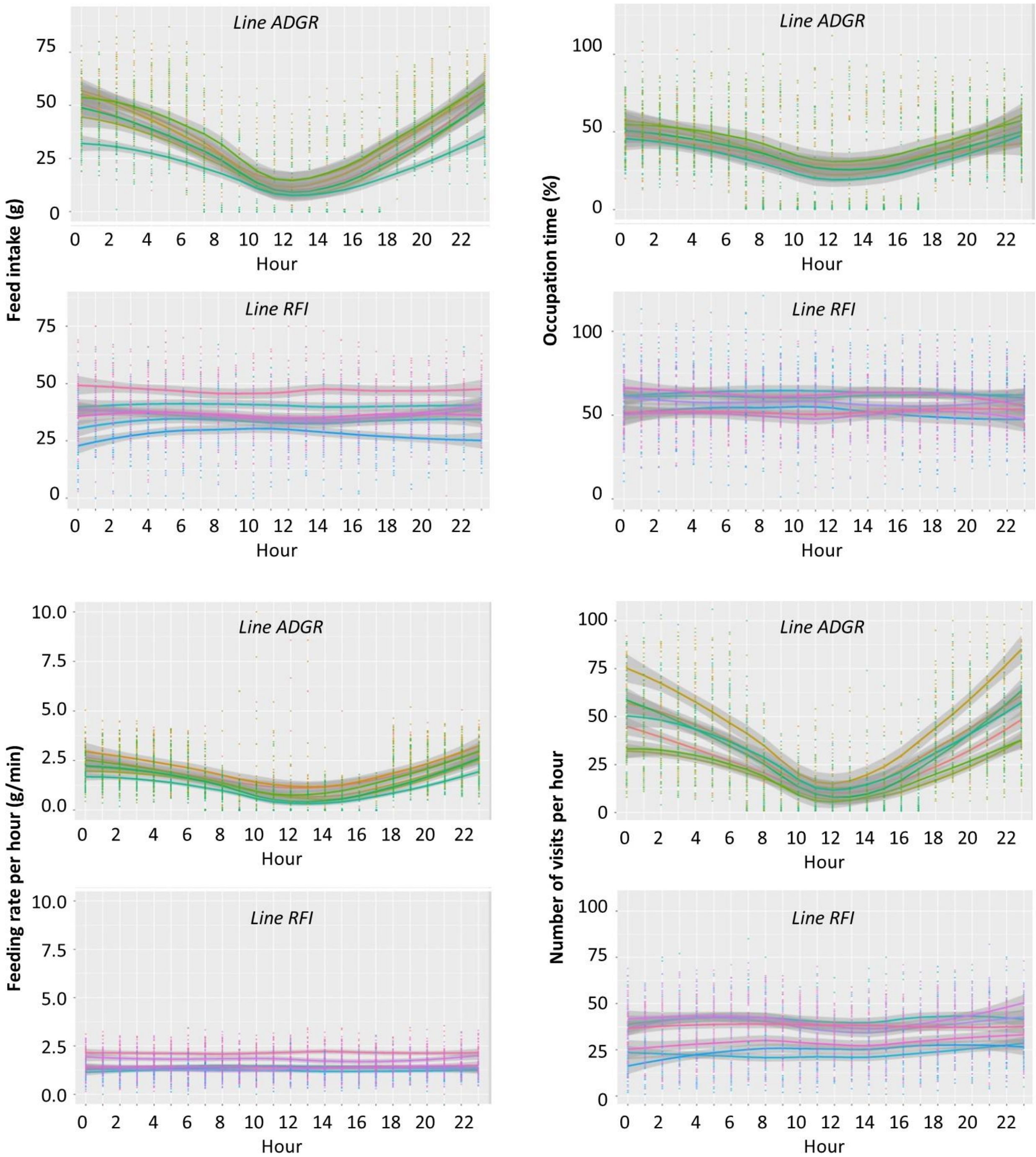


Figure 10. Hourly patterns of feeding behaviour traits, for a rabbit line selected for residual feed intake (RFI in blue-pink) and a rabbit line selected for daily gain under feed restriction (ADGR in green-orange) with seven animals per cage (T7). Each line represents a different cage.

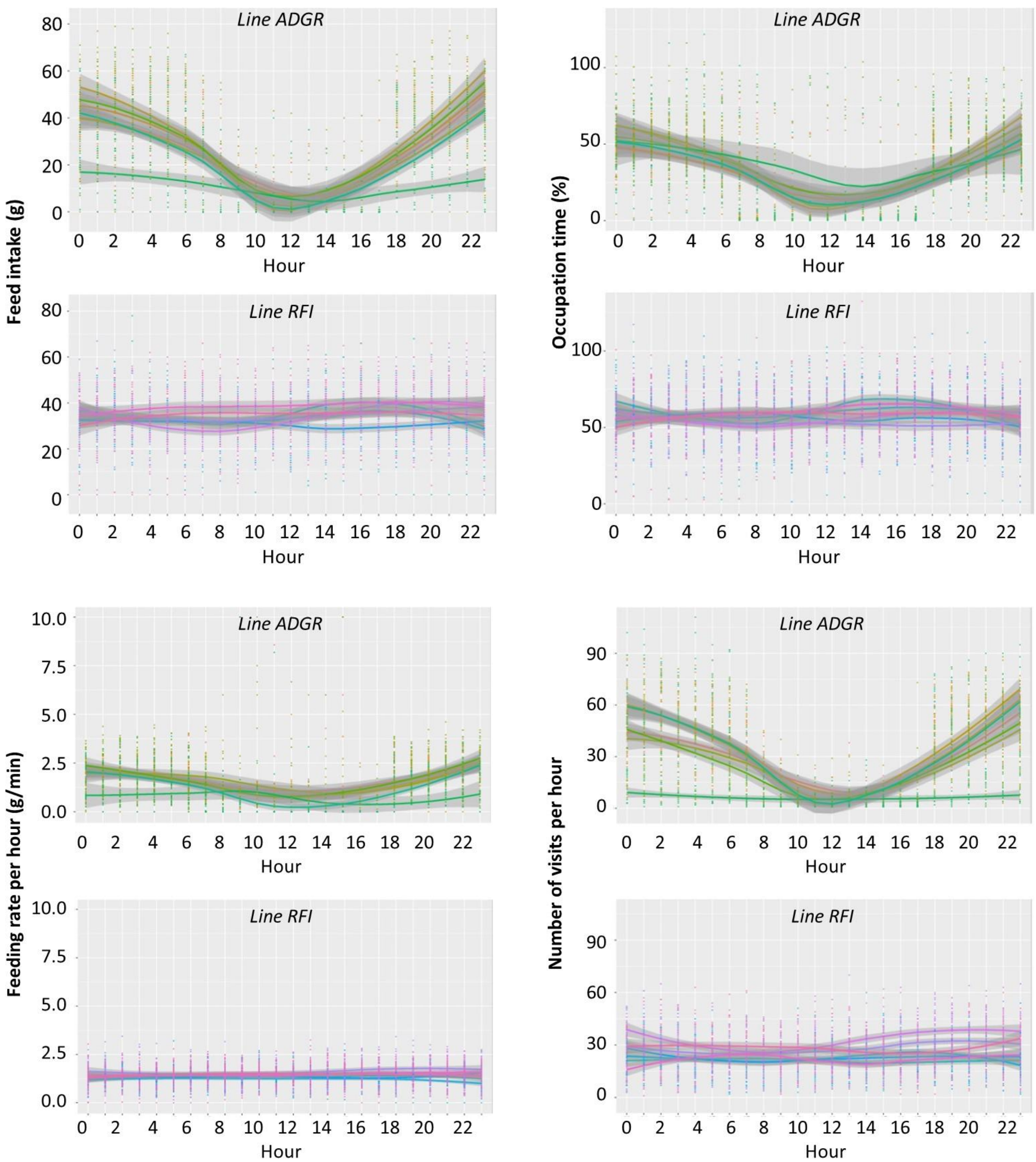


Figure 11. Hourly patterns of feeding behaviour traits, for a rabbit line selected for residual feed intake (RFI in blue-pink) and a rabbit line selected for daily gain under feed restriction (ADGR in green-orange) with six animals per cage (T6). Each line represents a different cage.

3.2.2.2. Individual level

Individual feeding behaviour traits can be deduced from data of elementary visits to the feeder This was done by aggregating visits on a day-animal basis. We calculated the day-animal sum of occupation time, number of visits and feed intake, mean of feeding rate, and time between consecutive visits. The daily data were averaged within animal. **Erreur ! Source du renvoi introuvable.** presents the mean and standard deviation of these traits, jointly with performance traits. Results are presented separately for trials T7 and T6, while distinguishing between feeding regimes (*ad libitum* and restricted feeding).

Table 5. Means (standard deviations), across individuals, within trial and feeding regime treatment for feeding behaviour and performance traits

Batch	T6		T7	
Feeding regime	Feed Restriction	Ad libitum	Feed Restriction	Ad libitum
Occupation time (min)	74.9 (18.0)	138 (19.9)	71.4 (12.2)	119 (22.0)
Feed intake (g/d)	89.7 (31.2)	140 (16.3)	98.1 (21.7)	126 (29.9)
Feeding rate (g/min)	1.8 (0.57)	1.46 (0.21)	2.14 (0.50)	1.49 (0.36)
Intervals between visits (sec)	1803 (2335)	948 (223)	1024 (379)	984 (473)
Number of visits	98.4 (42.7)	104 (22.1)	98.6 (32.0)	113 (35.6)
Feed conversion ratio (g/g)	3.85 (1.54)	3.27 (0.35)	4.47 (2.97)	3.04 (0.56)
Residual feed intake (g/d)	0.00 (27.7)	0.00 (13.0)	0.00 (17.8)	0.00 (18.6)
Average daily feed intake (g/d)	117.2 (27.7)	151 (17.2)	115.3 (25.0)	141.6 (30.8)
Average daily gain (g/d)	33.9 (10.4)	46.5 (6.06)	31.1 (10.8)	46.6 (6.06)

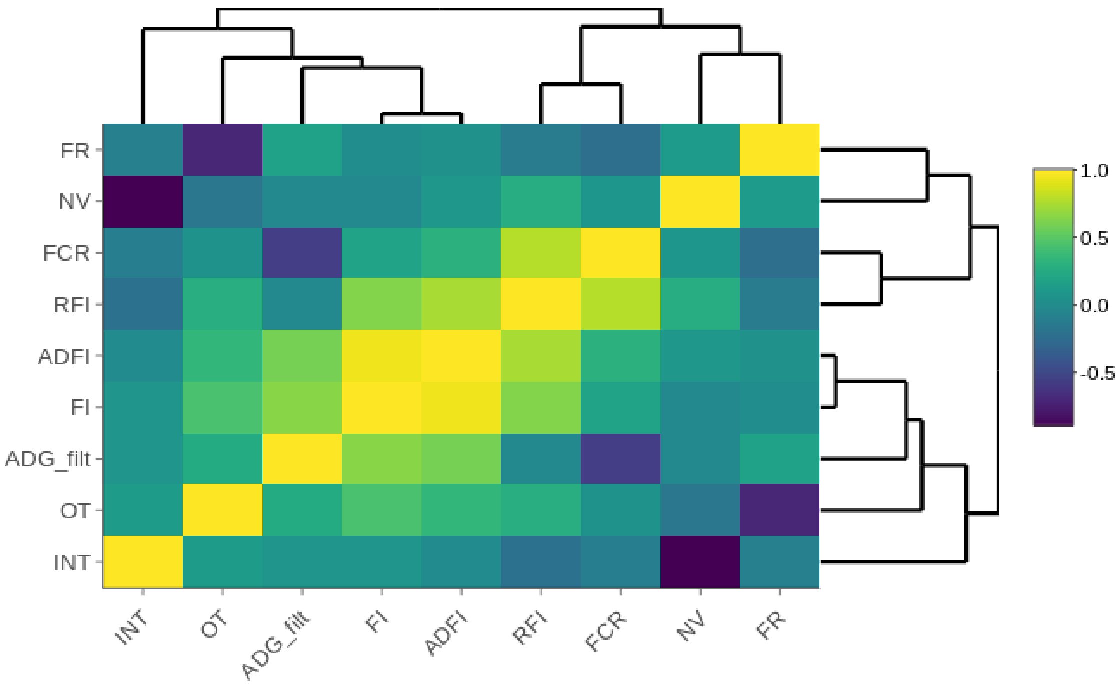
In Table 5, there are two traits representing daily feed intake of individual animals: "Feed intake" and "Average daily feed intake". "Feed intake" is computed by aggregating visits each day and averaging these across days during the fattening period. In this case, when information for a given day is not available, it is simply ignored. The "Average daily feed intake" is computed in a different way: before averaging across days, missing daily information is predicted using a three-parameter within-animal Legendre mixed linear model. Thus, when actual information is not available, a prediction of feed intake was used. For selection purposes, this second trait is the one used. Despite the difference in calculation, the correlation between both measurements is very high (>0.95), which can be seen in the dendograms given in Figures 12 and 13, in which both traits always cluster together.

The higher social pressure with seven instead of six animals per cage can also be seen in Table 5, as the individual daily occupation time is 20 minutes higher in the latter than in the former. Conversely, the time between consecutive visits of the same animal is about 35 seconds shorter in *ad libitum* fed animals with six animals per cage, compared with seven animals per cage This trait is highly variable, indicating that in some cases different blocks of the same visit were sometimes considered as different visits. When computing daily feed intake (to derive ADFI), this was taken into account by merging closely-spaced visits of the same animal. For animals under feed restriction, the interval between visits is increased as the time between the last visit before 6:00 and the first visit after 18:00 h was kept for calculations. No relevant difference was observed between T6 and T7 for individual feeding rate when animals were ad fed *ad libitum* (1.46 vs 1.49 g/min).

Figures 12 and 13 show images of the correlation matrix for each feeding regime group. This is a preliminary assessment of the correlation between individual feeding behaviour traits, and feed intake and feed efficiency traits. The first remarkable result is that the two defined feed efficiency traits (FCR and RFI) only cluster together when animals are *ad libitum* fed indicating that under feed restriction, other factors (e.g., example social interactions) might alter the biological and physiological meaning of these traits, relative to their interpretation under *ad libitum* feeding.

Under *ad libitum* feeding, the FCR and RFI generally cluster together with feeding rate, while growth clusters with occupation time (OT).

AD LIBITUM FEEDING (RFI)



FEED RESTRICTION (ADGR)

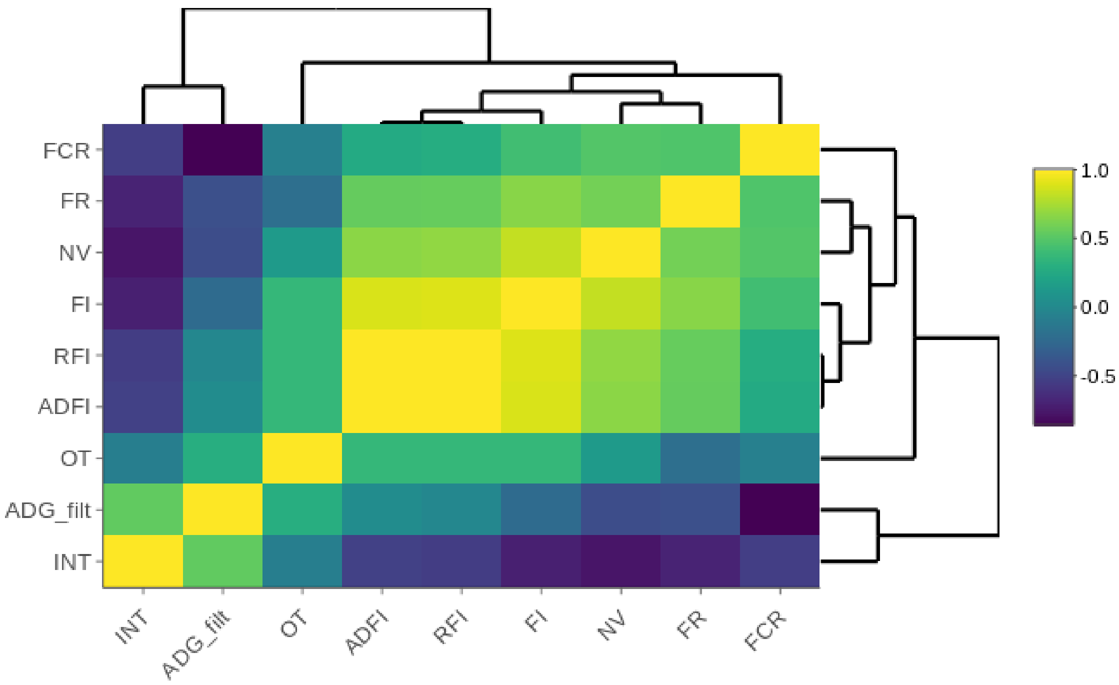
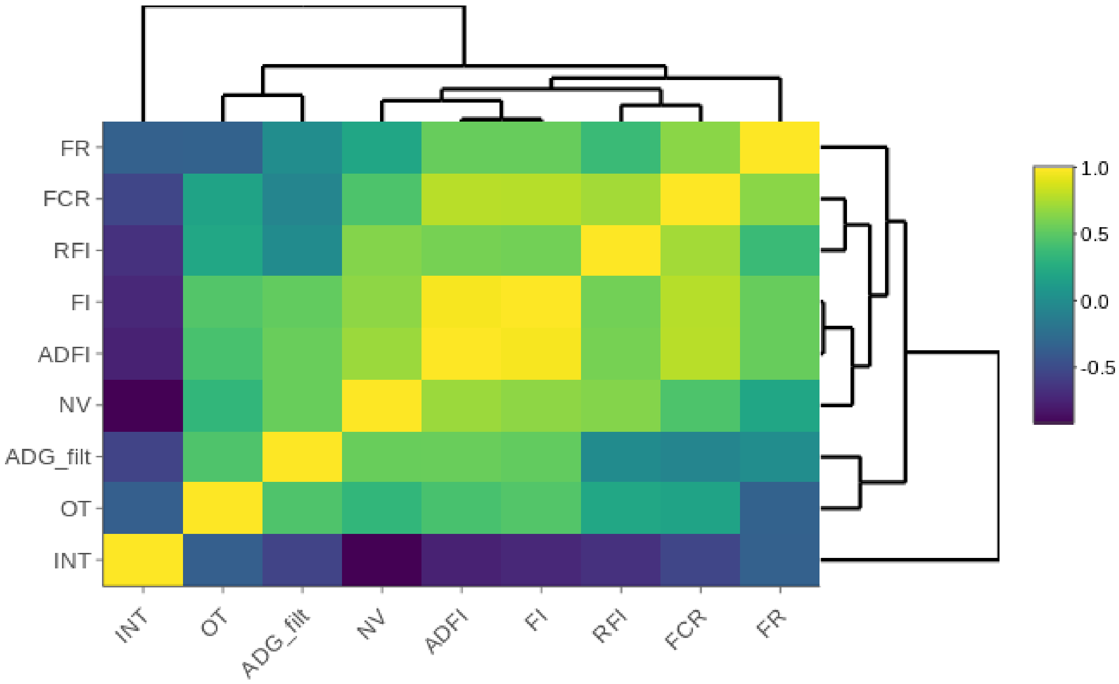


Figure 12. Phenotypic correlation matrix between performance and feeding behaviour traits when six rabbits are raised in a cage (T6). INT=interval between visits, ADG=average daily gain, OT=occupation time, ADFI=average daily feed intake, RFI=residual feed intake, FI=feed intake, NV=number of visits, FR=feeding rate, FCR=feed conversion ratio.

AD LIBITUM FEEDING (RFI)



FEED RESTRICTION (ADGR)

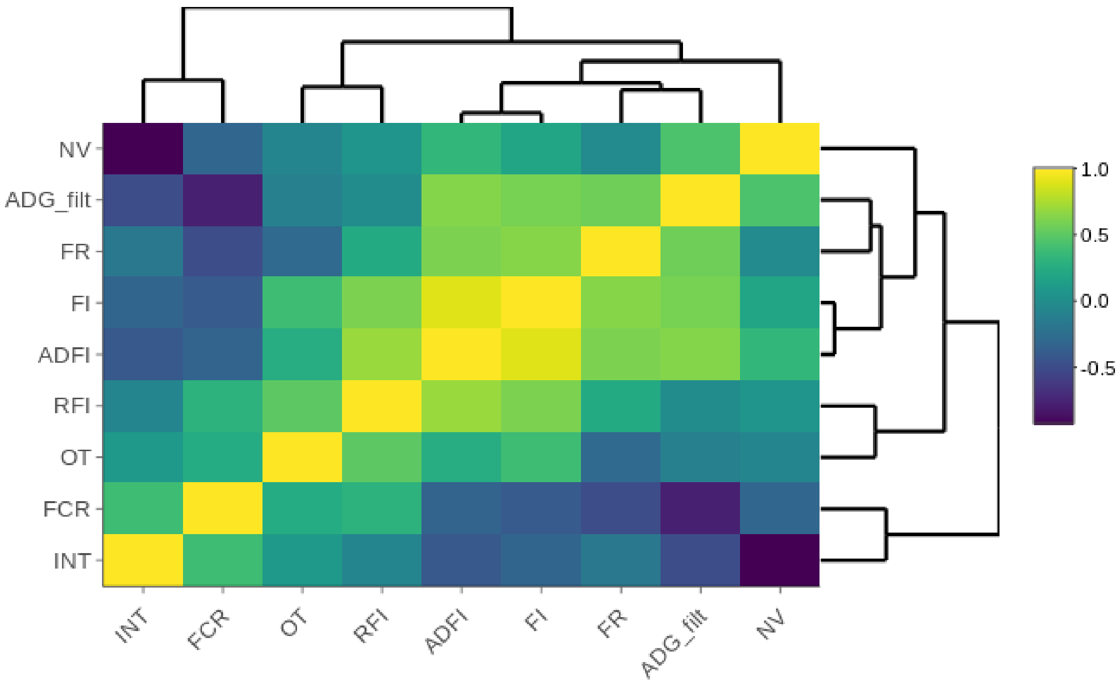


Figure 13. Phenotypic correlation matrix between performance and feeding behaviour traits when seven rabbits are raised in a cage (T7). INT=interval between visits, ADG=average daily gain, OT=occupation time, ADFI=average daily feed intake,, RFI=residual feed intake, FI=feed intake, NV=number of visits, FR=feeding rate, FCR=feed conversion ratio.

4. Conclusions

It seems that the use of electronic feeders modifies production performance of rabbits compared to conventional feeders, whereas no effect of the use of an individual feeding station on the performance of broilers is observed. The effects in rabbits could be due to a too large number of animals per feeder. The presence of a tunnel to access the feeder could also modify the behaviour of the rabbits and influence their access to the feeder. This tunnel is not present in the chicken feeding station. Further experiments will be conducted in rabbits in the Feed-a-Gene project and in future projects to disentangle the nature of the interaction between the animals and the electronic feeder, to improve protocols for their use.

In rabbits, important differences among batches of animals were observed, both in relation to feeding behaviour and to performance traits, either when animals were fed *ad libitum* or under feed restriction. Despite this, some common patterns in performance and feeding behaviour traits were observed. In chickens, total feed intake per bird was shown to differ between diets provided. Investigations with birds kept in a setting with feeding stations will be extended to the use of rapidly growing broilers. The use of feeding stations allowing measurement of individual feed intake via electronic feeders seems a promising approach for research targeted at improving nutrition, management, feed efficiency, and overall sustainability of broiler production.

Finally, we identified similar traits in both rabbits and in chickens relevant to performance and feeding behaviour such as number of visits to the feeding station, daily feed intake, time between visits, feeding rate, daily feeding duration, meal duration, and dynamics feed intake within a day. These traits are under further investigation as potential selection criteria considered in WP5 of the Feed-a-Gene project.

5. Presentations and publications of results

Kefi S. (2018). Development of an electronic feeding station to record feed intake in chickens. MSc thesis, Ecole Supérieure d'Agriculture de Mateur, Tunisia, 44 pp. *Supervision: Sandrine Mignon-Grasteau (INRA)*.

Sánchez J.P., M. Piles, M. Pascual, O. Rafel. (2018). Dispositivo para el control individual de consumo durante el engorde de conejos alojados en jaulas colectivas. Resultados Preliminares. XLIII Symposium de Cunicultura de ASESCU (Calamocha, Spain). 30/05/2018-31/05/2018. Oral Presentation.

6. References

Cook R. D. (1977). Detection of influential observations in linear regression. Technometrics. American Statistical Association 19: 15-18.

De Verdal H., Narcy A., Bastianelli D., Meme N., Urvoix S, Collin A, Le Bihan-Duval E., Mignon-Grasteau S. (2013). Genetic variability of metabolic characteristics in chickens selected for their ability to digest wheat. Journal of Animal Science 91: 2605-2615.

Kefi S. (2018). Development of an electronic feeding station to record feed intake in chickens. MSc thesis, Ecole Supérieure d'Agriculture de Mateur, Tunisia, 44 pp. Supervision: Sandrine Mignon-Grasteau (INRA).

Sánchez J.P., M. Piles, M. Pascual, O. Rafel. (2018). Dispositivo para el control individual de consumo durante el engorde de conejos alojados en jaulas colectivas. Resultados

Preliminares. XLIII Symposium de Cunicultura de ASESCU (Calamocha, Spain). 30/05/2018-31/05/2018. Oral Presentation.