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Precision Feeding in Laying Hens by Sound Technology

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In this study, a sound algorithm was developed to define the pecking sounds of laying hens. Furthermore, the relation between pecking sounds and feed intake of chickens was investigated to assess environmental impacts of precision feeding. The pecking sounds of 24 laying hens (Lohmann Brown) were recorded during 15 minutes by a microphone. Simultaneously, feed uptake quantity was automatically recorded using a weighing scale. The results demonstrate that 94% of the pecking sounds were correctly identified by the developed sound analysis method, whereas 6% of the identification results were false positives. Furthermore, a linear regression test was applied to define the coefficient of determination between the number of peckings and feed uptake and the number of peckings and feed intake of the birds, which respectively resulted in (R^2 = 0.993 and 0.991). Additionally, 91% of feed intake was succesfully detected by the proposed sound detection system. Furthermore, the results of the developed system were compared to the results of reference method in this case a weighing system measurements. Since strong correlations (R^2 = 0.991) were found between the number of peckings and feed intake of laying hens on the one hand and between the results of algorithm and reference methods on the other hand, the results showed that the proposed system has a big potential to be used to detect the feed intake and feed wastage of laying hens.

Key words: Laying hens, sound, pecking, feed uptake, poultry.

Yumurtacı Tavuklarda Ses Teknolojisi ile Hassas Yemleme

Bu çalışmada, yumurtacı tavukların gagalama seslerinin tespit edilmesi için bir ses algoritması geliştirilmiştir. Ayrıca, hassas yemlemenin çevresel etkilerini değerlendirmek için tavukların gagalama sesleri ve yem tüketimleri arasındaki ilişki incelenmiştir. Bir mikrofon ile 24 adet yumurtacı tavuğun (Lohmann Brown) gagalama sesleri 15 dakika boyunca kaydedilmiştir. Her bir tavuk için üç deney olmak üzere toplamda 72 deney gerçekleştirilmiştir. Aynı anda bir hassas terazi ile tavukların yem alımları otomatik olarak kaydedilmiştir. Önerilen ses tespit sistemi ile tavukların gagalama sesleri %94 lük bir doğruluk ve %6 lık bir hata payı tespit edilmiştir. Ayrıca, tavukların gagalama sayısı ve yem alımı ile gagalama sayısı ve yem tüketimi arasındaki determinasyon katsayısını belirlemek için sonuçları sırasıyla (R^2 = 0.993 and 0.991) olan bir lineer regresyon testi yapılmıştır. Ek olarak, önerilen ses tespit sistemi ile tavukların yem tüketimi %91 doğruluk ile izlenmiştir. Ayrıca, önerilen sistemin sonuçları ile referans metot (hassas terazi) sonuçları karşılaştırılmıştır. Bir taraftan tavukların gagalama sayıları ve yem tüketimleri, diğer taraftan da algoritma ile referans metotların sonuçları arasında güçlü bir ilişki (R^2 = 0.991) bulunduğundan, bu çalışmanın sonuçları geliştirilen sistemin, yumurtacı tavukların yem tüketimlerini ve yem kayıplarını izlemede kullanılması için büyük bir potansiyele sahip olduğunu göstermektedir.

Anahtar kelimeler: Yumurtacı tavuklar, Ses, gagalama, yem alımı, kümes hayvanları.

Introduction

The population growth in the world and economic growth in developing countries are expected to produce more and more demand for animal products such as meat, milk and eggs (FAO 2011). Thus, increasing livestock production in an environmentally manner needs to be a priority for livestock farming, and is linked with global food security.

However, livestock production is the primary tool for economic development. Thus, new technologies can improve livestock production while minimising environmental impacts, and can also improve natural resource management as a means of ensuring the health and safety of humans (FAO, 2011).

Today's technologies can enormously reduce the excretion of nutrients by animals, and as a consequence the land mass needed for the nutrients is reduced. Precision feeding can greatly reduce nutrient excretion, and therefore reduces the nutrients concentrations in manure to reduce environmental impacts of animals.

For precision feeding, computers and novel techniques have been applied to measure the feed intake, live weight and feed conversation ratio of birds (Hulsey and Martin 1991; Xin et al., 1993; Yo et al., 1997; Savory and Mann, 1999; Puma et al., 2001). Monitoring individual behaviours during researches was typically performed using a type of video imaging systems and weighing scales (Gates and Xin, 2008; Xuyong et al, 2011).

However, up to now, except of the study of Aydin et al., (2014) in literature, the similar methodologies have been used by defining poultry feed intake and feed wastage based on weighing scale data and video observation with manual labelling. Unfortunately, this manual labelling and observations are time-consuming and expensive for the farmers (Gates and Xin, 2001). Therefore, it was concluded that the event-based behavioural responses should be automatically collected by novel techniques (Xin et al., 1993; Gates and Xin, 2008; Gates et al., 1995; Persyn et al., 2004).

For example, a sound algorithm was developed to detect the pecking sounds of broilers. It was concluded by that the developed system can be used for monitoring the feed intake of broilers. However, it should also be stressed by that the results obtained were suitable for 28 and 39 days old broilers. Therefore, animal age and strains with different house conditions were believed to affect the frequency content of pecking sounds and needs further research with different strains at different age (Aydin et al., 2014).

Therefore, the objectives of this research were:

- to test the proposed sound detection system to automatically monitor the feed intake and feed wastage of laying hens (Lohmann Brown) as different strain with different animal age (34 weeks) as concluded in the study of Aydin et al., (2014),
- to assess the environmental impacts of precision feeding in laying hens.

Materials and Methods

Experimental setup

Experiments were performed with 24 laying hens during three consecutive days. Three experiments were conducted with each bird for a total of 72 experiments. Each experiment lasted for 15 minutes. Before each experiment a bird was placed in a separate cage with the dimensions of 50x50x50 cm (Figure 1). Afterwards, together with the pecking sounds of laying hens, all other sounds like vocalisation and ventilation sounds were automatically recorded by a microphone (Monacor ECM 3005) was positioned under the bottom of the feeding pan (Figure 1).

A microphone (30-20.000 Hz) was connected to PC by a preamplifier (Monacor SPR-6). The pecking sounds of laying hens were generated by the beak touching and dipping into the feed (layer feed) in the feeder.

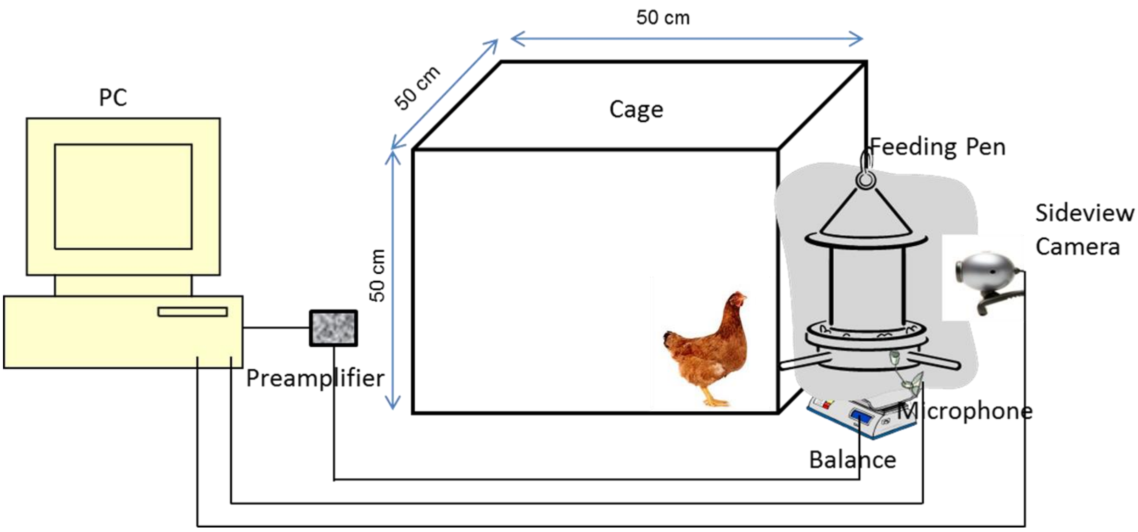

Figure 1. Laboratory setup for sound recordings of an individual chicken.

Şekil 1. Bireysel bir tavuğun ses kayıtları için laboratuvar düzeneği.

At the same time, a Logitech Webcam Pro 9000 with 3.7 mm Carl Zeiss® lens was fixed next to the cage at 50 cm distance (Figure 1). Furthermore, the feed uptake of laying hens was automatically recorded with 10 HZ frequency by a weighing scale (KERN PCB-250-3, with weighing range 250g and accuracy 0.001g). During the video recordings, light was kept on at 10 lux. After recording of all data, the recorded sounds were analysed by a sound analysis algorithm in MATLAB® (Mathworks). For validation of the proposed system, chicken peckings in the image data were manually labelled using the labelling tool developed by Leroy et al., (2005). In addition to that, a second validation was based on the measured weighing data was used.

Birds and housing

Experiments were conducted with 34 weeks old, 24 Lohmann Brown laying hens. Animals were vaccinated against Newcastle/infectious bronchitis (B1 or LaSota/Mass), Marek's disease (Turkey herpesvirus and SB-1) and other diseases by following standard procedure. First six weeks, a starter diet with 20% protein was given. From weeks six to weeks 20, a grower diet with 16 % protein, 1.2% calcium and from weeks 20 to on, a layer diet with 16% protein and 3% calcium were provided. Birds were kept in floor pens 0.5x0.5x0.5 m with wood shavings. Feed and water were freely available to birds during the experiments.

Sound analysis

The sound analysis procedure comprising of four steps was developed Matlab® software (MathWorks, Inc., Natick, Massachusetts, USA) and it was briefly explained in the studies of Aydin et al, (2014 and 2015). It consisted of: 1) definition of frequency ranges 2) sound filtering 3) sound extraction and 4) sound classification. The details of the algorithm for pecking sounds detection of broilers was presented by Aydin et al., (2014). However, the main diagram is shown in figure 2.

Calculation of feed intake

The feed uptakes of the birds were automatically and continuously measured by the developed sound algorithm detecting the pecking sounds of laying hens. Simultaneously, the feed uptake was recorded by a weighing scale while the feed wastage were collected and weighted manually after each experiment. The feed intake per experiment (FIPE) is defined as:

$$\mathrm{FIPE} = \mathrm{FUPE} - \mathrm{FWPE} \quad (1)$$

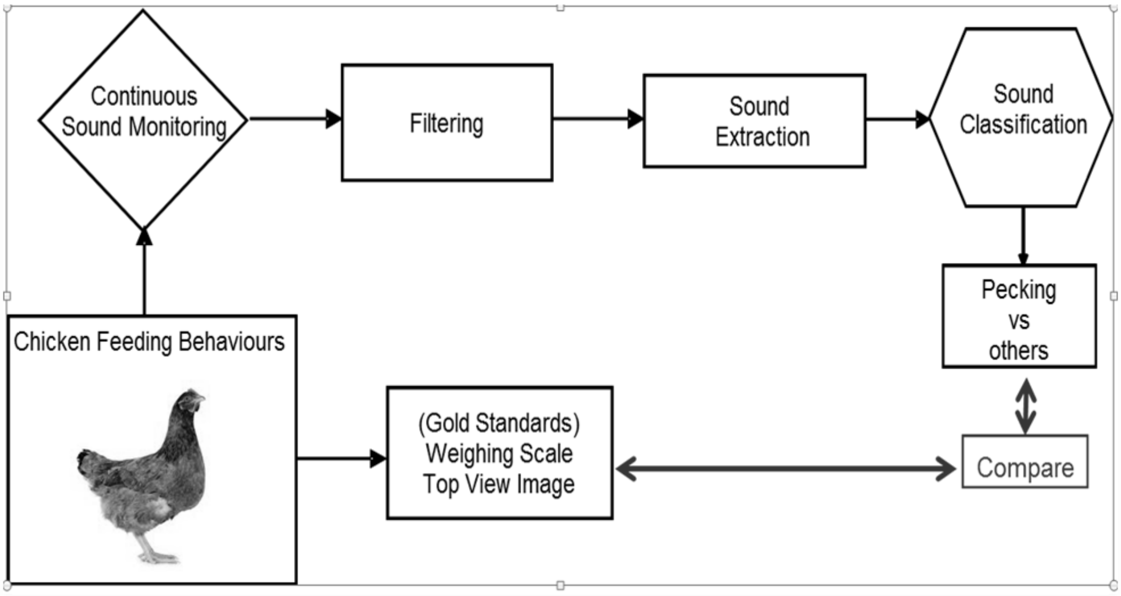

Figure 2. The flowchart for the developed signal processing.

Şekil 2. Geliştirilen sinyal işleme sistemi için akış şeması.

The feed intake per experiment (FIPE) is the quantity (g) of feed eaten by birds during the experiment. This value was calculated by subtracting the feed wastage per experiment (FWPE in g) of feed spilled to ground from the feed uptake per experiment (FUPE in g) of feed removed from feeder by the chicken (Aydin et al., 2014).

The feed intake per pecking (FIPP in g) is the quantity of feed ingested by chicken with each pecking. This value was calculated to the ratio between the total feed intake per experiment (FIPE in g) and the total number of pecking per experiment (NPPE) (Aydin et al., 2014).

$$FIPP = \frac{FIPE}{NPPE} \quad (2)$$

After the calculation of feed intake, the Analysis of Variance (Anova) was used to calculate statistical differences between the results of developed algorithm and reference method.

Results And Discussion

The first purpose of this research was to test the proposed system to continuously monitor the feed intake of laying hens (Lohmann Brown) as different strain at animal age 34 weeks as concluded in the study of Aydin et al., (2014). For this purpose, recorded sounds were examined and classified as either “pecking” or “other sounds” by the developed algorithm. Table 1 shows the total number of pecking sounds identified automatically by the proposed system and the total number of pecking sounds labelled visually by using the video recordings. False positives of the system were obtained when a sound of other nature were falsely identified as pecking. The pecking sounds were correctly identified by the proposed system with 94% accuracy, while the false positive results averaged low 6% (Table 1).

The second purpose of this research was to investigate the relation between pecking sounds and feed intake of laying hens. To define the total number of peckings, all recorded sounds were automatically examined by the proposed system. In addition to that, feed uptake (FUPE) of the birds was continuously measured by a weighing scale and automatically transferred to the PC. The lowest feed intake per pecking was found as 0.022 g in the third experiment of the fourth chicken. The highest feed intake per pecking was found as 0.027 g in the second experiment of the ninth chicken. The average feed intake per pecking was found as 0.025 g (Table 2).

Table 1. Accuracy results of the proposed sound detection system

Tablo 1. Önerilen ses tespit sisteminin doğruluk sonuçları

Data Set	Number of peckings (Algorithm) Mean±Std	Number of peckings (Video Labelling) Mean±Std	Accuracy (%) Mean±Std	False Positive Mean±Std
72	109±5	102±5	94±2	6±2

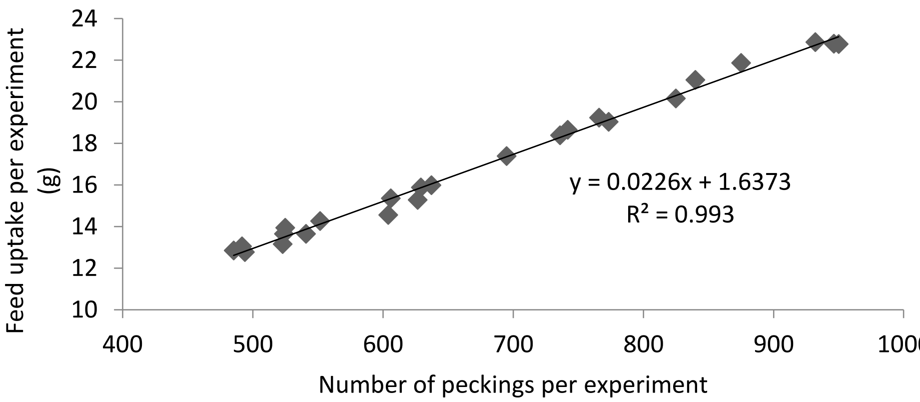

Figure 3. The relation between feed uptake and number of peckings of chickens per experiment

Şekil 3. Tavukların deney başına gagalama sayıları ve yem alımları arasındaki ilişki

Table 2. Number of pecking, feed uptake, feed wastage and feed intake of laying hens

Tablo 2. Yumurtacı tavukların gagalama sayısı, yem alımı, yem kaybı ve yem tüketimleri

Birds	Data Set	Time (min)	NPPE (Mean±Std)	FUPE (g) (Mean±Std)	FWPE (g) (Mean±Std)	FIPE (g) (Mean±Std)	FIPP (g) (Mean±Std)	FWPE (g) (%) (Mean±Std)
1.	3	45	932±3.00	22.87±4.83	0.14±0.07	22.73±4.77	0.024±0.0015[a]	0.61±0.11
2.	3	45	840±2.00	21.05±2.14	0.20±0.07	20.85±2.14	0.025±0.0011[a]	0.95±0.23
3.	3	45	541±2.65	13.65±2.11	0.10±0.02	13.55±2.07	0.025±0.0005[a]	0.73±0.06
4.	3	45	494±1.73	12.77±4.67	0.12±0.03	12.65±4.53	0.026±0.0019[a]	0.94±0.05
5.	3	45	825±1.00	20.15±1.34	0.14±0.03	20.01±1.43	0.024±0.0006[a]	0.69±0.05
6.	3	45	736±1.73	18.38±1.27	0.18±0.03	18.20±1.23	0.025±0.0020[a]	0.98±0.09
7.	3	45	523±3.00	13.15±3.16	0.26±0.02	12.89±3.12	0.025±0.0011[a]	1.98±0.18
8.	3	45	604±0.58	14.55±5.05	0.12±0.04	14.43±5.40	0.024±0.0006[a]	0.82±0.11
9.	3	45	946±1.73	22.78±7.79	0.20±0.09	22.58±7.71	0.024±0.0000[a]	0.88±0.08
10.	3	45	629±2.65	15.88±3.22	0.18±0.05	15.70±3.17	0.025±0.0006[a]	1.13±0.09
11.	3	45	766±0.58	19.23±9.04	0.21±0.11	19.02±8.93	0.025±0.0016[a]	1.09±0.07
12.	3	45	606±1.00	15.36±1.17	0.16±0.01	15.20±1.18	0.025±0.0015[a]	1.04±0.02
13.	3	45	637±0.58	15.98±3.24	0.19±0.05	15.79±3.19	0.025±0.0006[a]	1.19±0.09
14.	3	45	742±2.65	18.65±1.25	0.05±0.01	18.60±1.23	0.025±0.0021[a]	0.27±0.02
15.	3	45	496±6.02	13.93±2.12	0.13±0.03	13.79±2.09	0.026±0.0006[a]	0.93±0.06
16.	3	45	875±4.58	21.87±2.13	0.19±0.07	21.68±2.14	0.025±0.0012[a]	0.87±0.23
17.	3	45	524±3.51	13.65±5.95	0.05±0.05	13.60±5.90	0.026±0.0006[a]	0.37±0.02
18.	3	45	695±4.58	17.39±1.44	0.14±0.02	17.25±1.43	0.025±0.0006[a]	0.81±0.05
19.	3	45	552±2.65	14.26±3.26	0.14±0.02	14.12±3.32	0.026±0.0010[a]	0.98±0.03
20.	3	45	627±3.00	15.27±1.19	0.16±0.01	15.12±1.18	0.024±0.0015[a]	1.05±0.02
21.	3	45	950±4.58	22.77±7.79	0.20±0.09	22.58±7.71	0.024±0.0000[a]	0.88±0.08
22.	3	45	773±6.02	19.03±9.04	0.21±0.11	18.82±8.93	0.024±0.0015[a]	1.10±0.07
23.	3	45	485±2.65	12.85±4.77	0.13±0.04	12.73±4.73	0.026±0.0020[a]	1.01±0.06
24.	3	45	492±3.51	13.05±3.36	0.12±0.03	12.93±3.32	0.026±0.0010[a]	0.92±0.03

NPPE: Number of pecking per experiment, **FUPE:** Feed uptake per experiment, **FWPE:** Feed wastage per experiment, **FIPE:** Feed intake per experiment, **FIPP:** Feed intake per pecking.

a: Means within a column, with no superscript in common differ significantly ($p<0.05$).

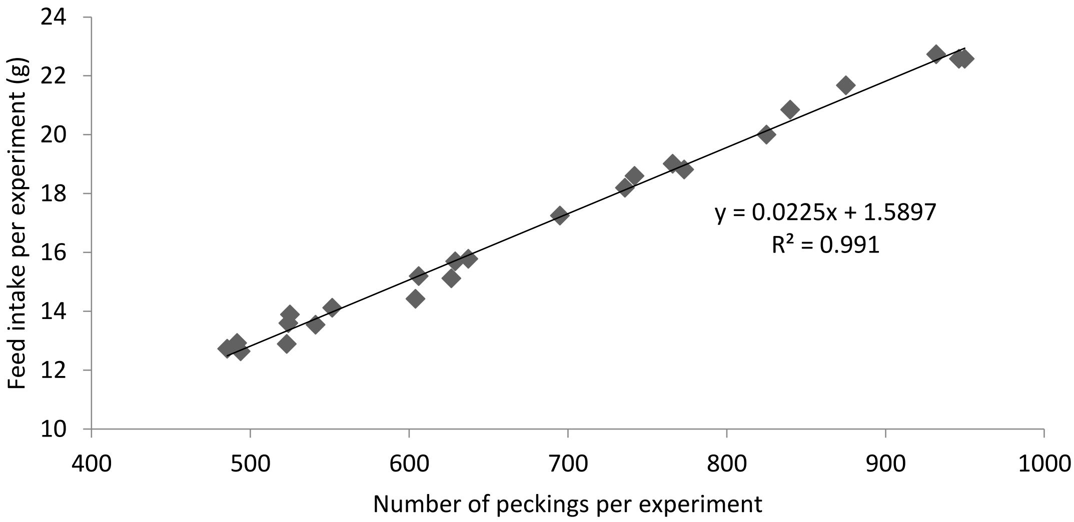

Figure 4. The relation between feed intake per experiment and number of peckings per experiment

Şekil 4. Tavukların deney başına gagalama sayıları ve yem tüketimleri arasındaki ilişki

The relation between the number of peckings and feed uptake of laying hens was examined and a linear relation was found between them. Also, a linear regression test was performed and the coefficient of determination (R2) was found to be 0.993 (Figure 3). On top of this high relation, 91% of feed intakes were succesfully measured by the proposed sound detection system. 0.93 percent of feed wastage was also correctly monitored by the proposed system.

Afterwards, the relation between feed intake per experiment and the number of peckings per experiment was also investigated and the coefficient of determination (R^2) was found to be 0.991 (Figure 4).

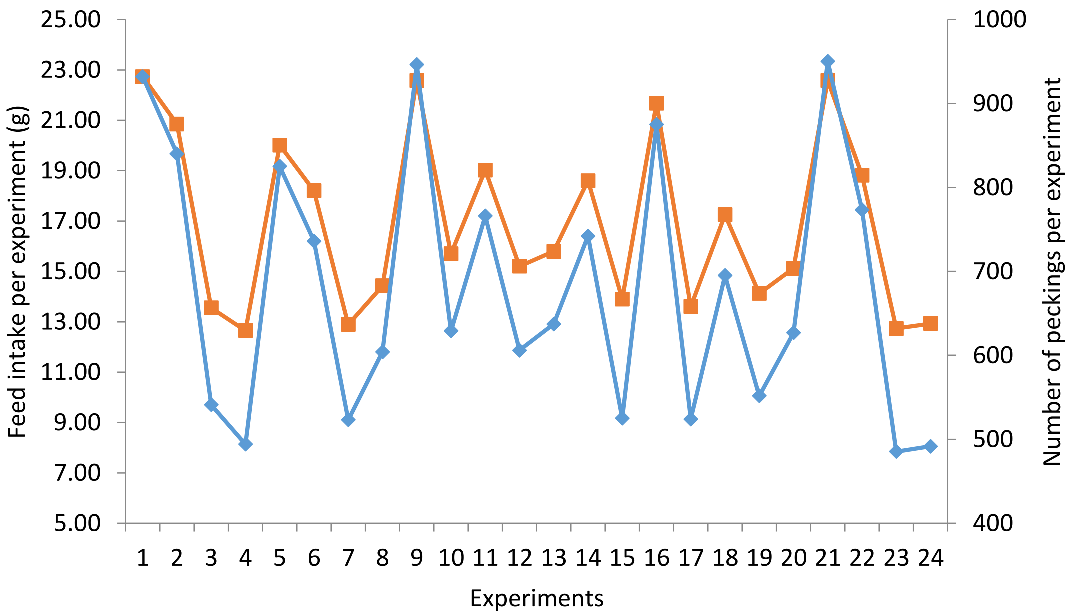

Figure 5. An examle of the relation between the number of peckings and feed intake of chickens

Şekil 5. Tavukların gagalama sayıları ile yem tüketimleri arasındaki ilişkinin bir örneği

As also can be seen in Figure 5, the number of peckings of the birds was highly correlated with the feed intake of laying hens.

A sound detection system was used to automatically detect peckings of laying hens. The system allowed recording the pecking sounds of laying hens by attaching the microphone under the feeder. Obtained data from the attached microphone were automatically analysed by the developed sound detection system and the results represents that 94% of the pecking sounds of laying hens were correctly identified, while the false positive results averaged low 6%. In addition to pecking sound identification the correlation between feed uptake, feed intake and number of peckings was investigated and a linear correlation was found between them.

Because of the correlation between the number of peckings and feed intake of the birds was resulted in R^2 = 0.991 the results strongly recommend that this pecking detection method has a big potential to be used as an instrument to monitor the feed intake of laying hens. The major advantage of this method is that measurements can be made automatically during the all life of the birds without disturbing them. However, implementing the proposed sound detection system to the commercial houses of laying hens will presumably introduce some problems that can affect the systems accuracy. For example, feed supplier and singing sounds of the birds will introduce a variety of sounds besides peckings. This probably will affect the frequency contents of the investigated sounds by the proposed system. Furthermore, the generated pecking sounds by the birds can be affected by the different types of feed. Therefore, further researches should be focus on the effects of different feed types on the generated pecking sounds.

Some studies to measure feed intake of poultry were previously published in literature (Hulsey and Martin, 1991; Savory and Mann, 1999; Yo et al., 1997; Gates and Xin, 2001; Persyn et al., 2004). For example, a system was developed by Hulsey and Martin, (1991) for evaluation of the feed intake and meal patterns. In another study, to detect the feed pecking of birds, three different techniques were compared by Yo et al., (1997). It was concluded in their study that videotaping suggestsa some development for the research of feed intake of birds. Another system was developed by Puma et al., (2001) to investigate the feeding behaviours of individual birds using an electronic balance. It was concluded by Puma et al., (2001) that the developed method may define feeding behaviours of the birds.

The results of this research are not straightly comparable with previously published researches in literature except of since their implementation referred to feed weight recordings and video observations different from the current sound technique. To detect the pecking sounds of broilers, a sound algorithm was developed by Aydin et al., (2014)and it was concluded in their research that the developed system can be used for monitoring the feed intake of broilers. However, it should also be stressed by that the results obtained were suitable for 28 day old broilers. Therefore, animal age and lineage with different house conditions were assumed to affect the frequency content of pecking sounds and needs more examinations with different strains at different age (Aydin et al., 2014).

When the results of this research were compared with the findings and conclusions of the study of Aydin et al., (2014) it was seen that there is a similarity between the results and the proposed sound detection system can also be used as a tool to automatically and continuously measure the feed intake of laying hens.

Precision feeding of laying hens with the proposed sound technology has also some opportunities to assess environmental impacts of feed technology. For example, when the feed intake and feed wastage of laying hens were precisely controlled by the proposed system, nutrient excretion and therefore the concentration of nutrients in manure can be reduced. As a consequence the land mass needed for the nutrients is reduced. However, excretion and manure composition can be affected by animal health and management. Maximising flock health can improve the efficiency of nutrient conversion into animal products such as meat, milk and eggs. Biosecurity procedures adopted under PLF will not only increase animal productivity, but also will reduce feed costs and nutrient excretion by limiting the introduction of new disease to the farm and providing measures to control or eliminate the spread of disease (Carter and Kim, 2013). Based on the global statistics, there will be an increasing demand for animal products in the future. If we are to balance animal productivity with nutrient output, producers, nutritionists and waste management specialists need to take concerted action to reduce the risks associated with animal wastes (Carter and Kim, 2013).

However, there are further opportunities to reduce environmental impact (Capper, 2011) such as reducing time to reach target weights, optimising diet formulation and minimising losses within the system. Environmental damage can be reduced by developing innovative animal health systems, precision feeding systems and recycling waste, all of which requires new knowledge and technology (FAO, 2011).

Conclusion

It is clear that the environmental damage of livestock animals can be reduced by developing innovative precision feeding systems which requires the new knowledge and technology. The sound technology was used to automatically define the pecking sounds and to measure the feed intake and feed wastage of laying hens in this research. The results represent that the pecking sounds of laying hens were correctly identified with 94% accuracy. Furthermore, 91% of feed intakes were correctly monitored by the developed sound detection system. Although the proposed system was tested on individual birds under laboratory conditions, the results represents that the presented sound detection system will be immensely useful for studying the feed intake and feed wastage of laying hens in future research. The results also showed that the developed sound detection system may be used for precision feeding in laying hens and this can allow precisely controlling and minimising feed losses within the system. The precision feeding can also increase feed efficiency of laying hens. As consequences, the environmental impact of precision feeding can be assessed by the proposed sound technology and the environmental damage of laying hens can be reduced by precision feeding system.

In any case the pertinence of the presented system should be tested with different strains at different age for a more accurate evaluation due to the animal age and different pathologic situations are assumed to affect the frequency content of pecking sounds. As author knowledge, till now, the proposed pecking sound technology was just tested on 28 and 39 days old Ross-308 broilers (Aydin et al, 2014 and 2015) and 34 weeks old Lehmann-brown laying hens in this research. Thus, this sound technique should be tested on young chickens to be sure whether it will work without problem with a few days' old birds before to use the developed system for the whole growing period. Additionally, different types of feed can also affect the sounds generated by birds. Thus, further researches should also clarify the effect of particle size and feed forms on the generated pecking sounds in poultry.

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