THE TIERED WIRE FLOOR SYSTEM FOR LAYING HENS

Development and testing of an alternative aviary for laying hens (1980-1987)

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In this book we shall try to give an account of the considerable efforts which have been made in recent years to develop an alternative for the battery cage system.

The results achieved so far could only be realized by an intensive and enthusiastic cooperation within the agricultural research, notably between the Institute of Agricultural Engineering in Wageningen (IMAG) and The Spelderholt Centre.

Furthermore the financial support of the Fund for the Welfare of Farm Animals and the EC have been of vital importance. The project has not yet been concluded. Only now a beginning has been made to put to the test the results found so far in a comparative study on a semipractical scale.

The tiered wire floor system is a major improvement to the battery cage system as far as animal welfare is concerned.

Also from a zootechnical point of view there are reasons for optimism. There are still questions to be answered as regards labour conditions and efficiency in management.

The greatest concern however is the control over the health situation in the new system. Therefore we intend to study these matters for at least two complete laying periods. In order to continue the staff will have to remain as enthusiastic as before and the willingness of external financers to contribute in the costs of the project is indispensable.

Hereby we are very happy to present the results reached so far.

All the people who have assisted in the project have been mentioned in the text. We should like to pay special attention to Mrs. J.M. Rommers and Messrs. C. ter Beek and H.J. Blokhuis who have compiled this booklet. Besides we'd like to acknowledge Mrs. M.A. de Hoop-Scherpenisse and Mrs. M.G. van Andel-Boswijk for translating the text and Mrs. D.M. Velner for typing the manuscript.

Dr.Ir. W. de Wit
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Het Spelderholt

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Summary

Reports and literature published within the framework of the project
1. INTRODUCTION

1.1 General

Over the past 25 years the public concern for the welfare of farm animals has greatly increased. One of the main reasons has been the strong intensification of animal husbandry systems (factory farming) in those years. In the Netherlands, as well as in several other countries in northwest Europe fierce discussion arose about the effects of animal welfare and consequently on the acceptability of these systems. In the early years these discussions were rather confusing, and subjective or false arguments were used both by those who supported and by those who opposed intensive animal husbandry systems. Due to a lack of scientific knowledge in the field of animal welfare, scientists initially could be of little help in the discussion.

In 1973 the Dutch National Board of Agricultural Research set up the committee for "Animal Welfare" which had to report on the problems involved in farm animal welfare. The committee's report was published in 1975. A general description of the problems for the various farm animals and recommendations for further scientific studies were presented in this report.

A large number of disadvantages of the different housing systems with regard to the welfare of laying hens were summed up. For the battery cage the limited space for the animal and the absence of litter and laying nests proved to be disadvantageous to animal behaviour. Feather pecking was among the problems noted in the application of the floor system.

Several research projects have been set up at Spelderholt, partly as a result of the recommendations of this committee. The development of an alternative cage for laying hens can be mentioned within this framework. This housing system should meet certain demands as regards animal welfare and certain criteria concerning productivity and labour conditions. Further attention was paid to the problems of floor eggs and feather pecking. The two former projects have come to a close and the results have been published. As for feather pecking the project is still running. Interim results have been published.
In this booklet a fourth project is described, titled "Research into alternatives for the battery cage in poultry housing". The Spelderholt in Beekbergen en the IMAG in Wageningen cooperate in this project. The form and background of this cooperation, as well as the objectives and financing of the project will be discussed in the following sections. In Chapter 2 the history of the tiered wire floor system developed in this project is dealt with. Chapter 3 describes a few of the results of experiments with the system, performed up till the present day. In Chapter 4 plans for the testing of the developed system are discussed. Finally a description is given of the construction and design of a testing accommodation newly built for this purpose.

1.2 The project group

With reference to the above-mentioned report of the committee for animal welfare various disciplines both at Spelderholt and at IMAG tried to form new ideas to come to a housing system for laying hens which would be more considerate of the welfare of the animals. Spelderholt concentrated mainly upon the zootechnical and ethological aspects of the problem, whereas the IMAG worked on the design and construction. This resulted quite logically in the formation of a joint project group in 1980. Over the years this project group was frequently altered through various circumstances. At the moment (December 1987) the project groups consists of the following people:

Zootechnics
- Ing. A.M.J. Donkers (Spelderholt)
- Ir. D.A. Ehlhardt (project leader, Spelderholt)
- Mrs. Ing. C.L.M. Gerritsen (Spelderholt)
- Ir. P.I. Haartsen (project leader, IMAG)

Technics
- C. ter Beek (IMAG)
- W.F. Frederiks (IMAG)
- A. Overduin (Spelderholt)

Behaviour
- Ir. H.J. Blokhuys (Spelderholt)
- Mrs. Ing. J.M. Rommers (Spelderholt)

Animal care
- W.G.M. Hiskemuller (Spelderholt)
- W.C. Veeger (Spelderholt)
The following persons contributed greatly in the earlier stages of the project:

Ing. A. Cappon (technics, IMAG)
Ir. P.B.A. van der Heijde (zootechnics, IMAG)
E. Laseur (zootechnics, Spelderholt)
Ir. J.A.M. Voermans (project leader, IMAG)

The following students have likewise given their support:

Ing. D. Pullen (CHLS Dronten)
Ir. A.A.M. de Ruyter (LU Wageningen)
Mrs. Ing. E. Liekens (RULS Deventer)
W. Muilwijk (CHLS Dronten)

1.3 Starting-points and pre-conditions

Alternative systems for laying hens can be roughly divided into models that are based on the "cage principle", and models in which the animals can move about freely throughout the house and which are more similar to traditional floor systems. Considering the fact that in a different project alternative cages were already applied, the project group concentrated only on the latter model. From the outset of the project the objective has been to develop an alternative

- in which the welfare of the hens is better than in the battery cage;
- which can be commercially competitive with the battery cage.

On the basis of these starting-points a number of pre-conditions were made that an alternative system should have to meet. The first starting-point led to the following pre-conditions:

- the freedom of movement for the hens must be considerably greater than in the present battery cages. The project group took the housing density standard as applied to deep litter hens (7 birds per m²) as a guideline.
- litter material must be present for the hens to peck and scratch and dustbathe.
- the hens must have laying nests.

The second starting-point resulted in the following list of preconditions:

- the minimum number of hens per m² house must be 20. Among other things this is important in order to maintain a temperature of 20°C in summer and winter without additional heating, thus keeping the cost of feeding at an acceptable level.
- production must be good with a maximum of 2% floor eggs.
- egg collection and manure removal must be mechanized.
- mortality may not be higher than 0.5% per month.
- second quality eggs, floor eggs included, may not exceed 10%.
- the litter should be kept dry (over 60% dry matter).
- dry manure must be removable at weekly intervals.
- good flock supervision must be possible.
- the number of hens per unit of manpower must be comparable to that in 3-tier cages.

The above-mentioned pre-conditions formed the basis of the project and determined the approach. Already in the designing stage of a prototype these conditions were observed as much as possible (e.g. the presence of litter, the number of animals per m²). However, only when a prototype is functioning the design in question can be checked on its really meeting the pre-conditions (e.g. can the hens actually use the litter and is there sufficient flock supervision). So the first stage of the project had a rather pragmatic character, aimed at a practical functioning of the prototypes. The trials did not last long and succeeded each other quickly, while each time small modifications were installed in the design. In a later stage of the project more structural zootechnical, ethological and technical research was carried out. A number of variables, such as labour need and production characteristics, cannot be measured reliably in small-scale prototypes. This necessitates the construction of larger units. The project has now reached this stage.

1.4 Financing

Initially the project was financed for several years by the cooperating institutes. From 1984 the project was supported by the Fund for the Welfare of Farm Animals and in 1987 the EC offered its financial support as well. The department of Agriculture has granted three extra functions to be filled from 1986-1989 in addition to the efforts of the permanent staff of both institutes. The following survey shows the expenses of the project over the past period. The contributions of Spelderholt and IMAG are inclusive of staff salaries and overhead expenses.
<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution Spelderholt</td>
<td>£1,2900.000</td>
</tr>
<tr>
<td>Contribution IMAG</td>
<td>£1,1900.000</td>
</tr>
<tr>
<td>Subsidy Fund for Animal Welfare</td>
<td>£1,550.000</td>
</tr>
<tr>
<td>Subsidy EC</td>
<td>£1,100.000</td>
</tr>
</tbody>
</table>
2. HISTORY OF THE DEVELOPMENT OF THE TIERED WIRE FLOOR SYSTEM

2.1 Introduction

In the history of the development of the tiered wire floor system three stages can be roughly discerned:

- Preliminary research - gathering information 1980-1981
  - literature study
  - formulation of the problem, feasibility, financing
  - testing definitions

- Design stage - design 1981-1986
  - testing
  - adaptation
  - testing
  - etc.

- Testing stage - construction final design 1986-1989
  - comparative research

In the dates of these stages there is a certain overlap. The preliminary research stage was closed at the formulation of the plan for the design of the new housing system and the way in which this should take place. The design stage had more or less started during preliminary research while ideas were being framed. Without such ideas the feasibility of the project could not be assessed nor could there ever be a basis for an application for financial support.

During the design stage we were confronted with several aspects of housing which could not very well be assessed simultaneously. Indeed the mutual influences of the different details were considered, but a complete picture of its practical functioning could not be drawn yet. The aim of the testing stage, which the project has now reached, is to verify whether the housing system comes up to the starting-points mentioned in Chapter 1:

- the welfare of the hens must be greater than in the battery cage.
- the system should be able to compete commercially with the battery cage.
For this purpose behavioural research is carried out, the results of which will be discussed in Chapter 3. A comparative research will be carried out in a house especially built for this project. Of this latter research no results are available yet. Chapter 4 describes the proposed research and the new house. In the following section the above-mentioned first two stages will be dealt with.

2.2 Preliminary research

Exploratory discussions between staff members of IMAG and Spelderholt soon revealed that detailed information with regard to some behaviour patterns of laying hens (egg laying, movements, resting, feather pecking) was insufficient and could hardly be taken into consideration in the design of the system. Thus the project should in all stages be backed up by behavioural research, especially with regard to the use of space by hens. Separate projects (feather pecking, egg laying), as well as research within the project of alternative housing were considered to be part of such a back-up.

During the information stage furthermore, the joint team focused on those systems abroad that already resembled aviaries, mainly in order to avoid the defects which had been encountered there. During the preliminary research stage contacts were made and regularly maintained with research teams in Germany (Celle), Great Britain (Gleadthorpe, Auchincruive and Aberdeen) and Switzerland (Basle, Zurich).

From the very start it was clear that there were several concrete questions to be answered in an experiment, before a plan of action could be formulated. These questions were mainly connected with the use of space and movements of the hens when released in a pen with facilities such as nests, litter, perches, feed and water supplies at different levels. The experiment was to be performed on the basis of three different scenarios.

1. Hens do not use the vertical tiers at different levels or if they do, insufficiently and improperly.
2. Hens do use the tiers, but only if they can walk from one level to another.
3. Hens naturally use the tiers even when they have to jump or fly.
The "pessimistic" scenario 1 led to the design in figure 1. In this design the hens could only move about in one of the horizontal three levels built on top of each other. All levels were provided with the same facilities (litter, laying nests, feed and drinking water). Scenario 2 was realized in a design in which hens could reach three different levels by means of spiral staircases, although it was also possible for them to fly from some parts to others (figure 2). The design in figure 3 was a result of scenario 3 and it was built to enable the hens to jump from the floor to the lowest tier level and by way of the perches in between again to a higher floor. On the litter level, the floor of the pen, no feed or drinking water were supplied. At several levels above the litter however, perches were installed offering the hens a place to escape to, or to rest.

Figure 1  Schematic cross section of the design according to scenario 1.
Figure 2 Schematic cross section of the design according to scenario 2.

Figure 3 Schematic cross section of the design according to scenario 3.
IMAG and Spelderholt agreed to finance both the construction of these prototypes and a short experiment (1980). On the basis of the results a plan of action would then be formulated which was to be carried out provided that other financers would also contribute. The experiment was carried out with approximately 300 laying hens of a brown egg laying strain in each design in a naturally ventilated daylight house at Spelderholt. On the basis of the egg production, feed consumption and four daily animal counts at different locations, the following conclusions could be drawn after 14 weeks of production:

- hens spread equally over the different levels of the pen and made frequent use of the litter floor.
- the models both of figure 2 and of figure 3 held certain possibilities on the basis of zootechnical results.
- the model of figure 2 was inferior to the model of figure 3 as regards construction and labour.
- more attention should be paid to the design from the point of view of maintenance and labour facilities.

There were several reports on the results (see list of reports and publications). On the basis of these results a workplan and an estimate of the costs were drawn up. These were then presented to, among others, the Fund for the Welfare of Farm Animals together with an application for a grant. In the workplan the aim of the project was formulated and the pre-conditions which the new design of the housing system should meet, were classified (see Chapter 1.3).

2.3 The design stage

The proposed procedure implied, on the basis of consensus in the project group, that newly designed models would be tested, thereby applying a number of criteria which will be described hereafter. The tests were to take place in a laying house at Spelderholt, during short periods in which as many data as possible had to be collected about production and the use of space. Although short-term tests are less suitable for determining the usability of a system, this procedure offers the following advantages:
any defects in the design are soon detected and can be quickly mended in a next prototype.

In housing systems with laying nests the floor eggs present a major problem. This problem especially presents itself during the peak production period and lessens after that. Thus the trial period must cover a period when the hens start laying until and including the peak production.

Preliminary research demonstrated that the following technical provisions had to be incorporated in the prototypes:
- the use of steel wire floors.
- manure collection under the floors.
- the use of individual roll-away nests.

All three designs needed technical improvements that had to be tested in prototypes. Moreover at the outset the following questions arose:
- number and width of the tiers.
- position and framework of the wire floors.
- system for the removal of manure.
- position of the laying nests.
- feeding system and where to place this.
- drinking system and where to place this.

Before making a trial design a systematic testing plan was drawn up, including the following assessment criteria:
- production of nest eggs (n.e.).
- production of floor eggs (f.e.).
- localization of n.e. and f.e.
- feed consumption - quantity
  - location
- spreading of animals - during the day
  - at night
- litter condition
2.3.1 The first prototypes

Initially with other views in mind 80 hens were kept in a different pen during the preliminary research. This wire pen was cubic, from all sides accessible and measured 2 by 2 metres.

The design is shown in figure 4. This layout was considerably more satisfactory as regards maintenance and labour, egg collection and manure removal, than the designs mentioned in 2.2. Moreover supervision of the flock was quite good.

Figure 4 Schematic cross section of the "cubic" prototype (type 1).

However, owing to the relative high density the litter soon became moist. The layout was very suitable for animal observation. This was done to count the movements of the hens and to determine their location preference.
It soon appeared that during the day most hens remained longest in the feeding places. By moving the feeders it turned out to be possible to influence the use of space. In this way the litter condition improved rapidly when the hens were no longer fed at litter level. Also the number of floor eggs decreased soon after this.

The lower laying nests were provide with litter; those on the tiers were in the form of roll-away nests. 80% of the nest eggs were laid in the litter nests.

Continually alterations were made in the prototype while the same hens remained present. In this way some effect could indeed be reached, e.g. on the location preference and the percentage of floor eggs, but it was difficult to assess this effect. Therefore pullets were always used in follow-up tests.

The experiences of the preliminary research and the cubic model were used in the design of the next prototypes as follows:
- the laying nests must be separated from the wire floors in order to be accessible on both sides for the attendant.
- the perches must be combined with one of several wire floors to prevent the night manure from dropping into the litter.
- the design must take into account the mechanical feeding and mechanical removal of manure and eggs.
- feeding and water provisions and places where floor eggs are to be expected must be easily accessible.

These principles led to two different solutions which unfortunately could not be tested out simultaneously (figures 5 and 6).

The models differed in the following respects:
- the number of tiers.
- the location of the laying nests.

A survey of the various characteristics of these prototypes is recorded in table 1.
Figure 5  Schematic cross section of the tiered wire floor system (type 2).

Figure 6  Schematic cross section of the tiered wire floor system (type 3).
Table 1 Characteristics of two different prototypes (figures 5 and 6).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Type 2</th>
<th>Type 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor surface (m$^2$)</td>
<td>19.8</td>
<td>18.2</td>
</tr>
<tr>
<td>Number of tiers on the left</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Number of tiers on the right</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Width of tiers (cm)</td>
<td>170</td>
<td>170</td>
</tr>
<tr>
<td>Width of service aisles (cm)</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Number of hens</td>
<td>393</td>
<td>317</td>
</tr>
<tr>
<td>Number of hens/m$^2$ floor surface</td>
<td>19.8</td>
<td>17.5</td>
</tr>
<tr>
<td>Number cm$^2$ floor space/hen</td>
<td>1282</td>
<td>1219</td>
</tr>
<tr>
<td>Number of hens per laying nest</td>
<td>5.2</td>
<td>4.0</td>
</tr>
<tr>
<td>cm$^2$ feeding trough per hen</td>
<td>9.0 (10.5)*</td>
<td>11.4</td>
</tr>
</tbody>
</table>

*After addition extra feeding troughs.

On purpose the prototypes differed widely in construction so that any equivalent results would show up the insignificance of these differences for the technical results. Great differences in technical results would in a relatively short time indicate the right direction for further research. On comparison these two prototypes showed very great differences, especially in the percentage of floor eggs, owing to the location of the nests. The main production characteristics have been compiled in table 2.
Table 2 Survey of production of prototypes 2 and 3 (figures 5 and 6).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Type 2</th>
<th>Type 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of hens housed</td>
<td>393</td>
<td>317</td>
</tr>
<tr>
<td>Number of hens end of trial</td>
<td>391</td>
<td>314</td>
</tr>
<tr>
<td>Number of hens per m$^2$ floor surface</td>
<td>19.8</td>
<td>17.5</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>0.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Age (days) at housing</td>
<td>133</td>
<td>128</td>
</tr>
<tr>
<td>Age (days) at first egg</td>
<td>140</td>
<td>136</td>
</tr>
<tr>
<td>Age (days) at 50% production</td>
<td>155</td>
<td>164</td>
</tr>
<tr>
<td>Age (days) at peak production</td>
<td>180</td>
<td>189</td>
</tr>
<tr>
<td>Peak production (%)</td>
<td>91.7</td>
<td>83.4</td>
</tr>
<tr>
<td>Floor eggs at 50% production</td>
<td>9.3</td>
<td>59.4</td>
</tr>
<tr>
<td>Floor eggs maximum (%)</td>
<td>12.5</td>
<td>98.1</td>
</tr>
<tr>
<td>Floor eggs end of trial</td>
<td>2.6</td>
<td>44.6</td>
</tr>
<tr>
<td>Floor eggs average (%)</td>
<td>5.9</td>
<td>54.1</td>
</tr>
<tr>
<td>Number of control days</td>
<td>64</td>
<td>55</td>
</tr>
</tbody>
</table>

Two conclusions could be drawn from this trial which were of great importance for future developments:
- in aviary systems laying nests should not be on the floor.
- the number of tiers must be three.

The first conclusion could be drawn on the basis of the total percentage of floor eggs and their locations. It appeared that in both arrangements most floor eggs were found in the vicinity of the feeding troughs on the wire floors. In the prototype, as shown in figure 5, most eggs were laid in the upper tiers of the "nest block" and only few in the lower tier and in the nests on the floor under the tiers.
The course of nest preference of the entire flock in this model during 64 control days is shown in figure 7.
Figure 7 Course of the percentage of nest eggs in the total egg production in the design from figure 5 (type 2).

(1 = upper tier, 5 = lower tier, 6 = nests under tiers).

* At no time more than 0.5% of the eggs were laid in nest tier 5 (lower) and in the nests under the tiers (6).

The experiences with the flock in the prototype, as in figure 6, were considerably worse, which resulted in an untimely end of the trial. The hens scarcely used the nests although this model was an exact copy of the prototype in figure 4, but in a double-sized construction. The housing density seemed to be too high. From the very start the hens in the prototype from figure 5 moved about with remarkable ease. The different levels in both tiered wire floors probably contributed greatly to this effect.
The preference of laying hens for litter nests was known at that moment from research on the first prototype, from international literature and from research at Spelderholt. It seemed necessary however to apply a roll-away nest, which was more attractive than the nests with wire mesh bottom or P.V.C.-coated green wire bottom which had been in use until then. In a separate trial with WL-hens in pens with litter floors four different laying nest bottoms were compared. One bottom proved clearly superior, that is Astroturf artificial grass. This bottom was obviously accepted more readily by the hens than the bottoms used so far. Here too the hens turned out to prefer the upper tier of the nests.

After this experiment only wooden nests of the "Van Gent" model with a roll-away bottom of Astroturf artificial grass were used during this development research.

**Figure 8** Schematic cross section of "Van Gent" laying nests with bottom of artificial grass.

The prototype, as in figure 5, served as a model for the first attempt to equip a regular-sized pen with the tiered wire floor system. For this purpose two possible constructions were invented, as illustrated in figures 9a and b. In both drafts laying nests are alternated with tiered wire floors.
Figure 9 Two possible constructions of the tiered wire floor system.

Figure 9a

Figure 9b
As it was not clear beforehand which of the two would be preferable, a long-term comparative test was suggested in which an additional experiment could be carried out with the tiered wire construction and the semi-mechanical removal of manure and eggs.

Two constructions were built, as shown in figures 10a and b, each of them being 10 m long. The construction was carried out in angle iron and steel wire floors, sloping to both sides so that floor eggs would roll down to the egg collection channel. The tiers had a width of 170 cm.

At a density of 20 hens per m² floor space each construction could house about 1250 hens.

The test was carried out with laying hens which had been reared outside Spelderholt. Right at the outset problems arose when it appeared that all pullets remained on the litter floor and could not reach feed and water. A number of measures prevented them from starving and gradually they adjusted to their environment. On account of the fact that in one model (figure 10a) the tiers were of different heights the adaptation took place sooner than in the symmetric construction (figure 10b). Another disadvantage of the last-mentioned model was that vertical movement of the hens had to take place by means of the construction of laying nests in the middle. As a consequence the nests were not only used as a staircase but also as a place to rest and sleep, which resulted in serious contamination of the eggs.

Apart from that there were no serious problems with floor eggs, in spite of the poor start. On the contrary, in both constructions more than 98% of the eggs were laid in the nests. However, once again 48% (model figure 10a) and 60% respectively (model figure 10b) of the egg production was observed to be laid in the top tier of the nest boxes.

In one of the constructions the manure removal system failed completely so that the trial had to be discontinued earlier than planned.

Important conclusions from this experiment were:

- that more understanding of the rearing conditions stipulated by this system should be acquired as far as adaptation problems are concerned after housing (see Chapter 3.2).

- that the floor space is used more efficiently in the construction shown in figure 9a than in the construction of figure 9b.
Figure 10 Schematic cross section of the two experimental constructions with a length of 10 meters.

Figure 10a

Figure 10b
2.3.2 The final design

Together with the conclusion of this experiment the foundation was laid for the final design of the tiered wire floor system as shown in figure 11. This design was drawn in the beginning of 1984. At the same time the desired procedure for the research was formulated. During two years this should be focused on perfectioning the details, such as the proper width of the tiers, desired replacement of the wooden parts by synthetics in connection with ectoparasites and on finding the right feeding system in connection with feed waste.

Figure 11 Schematic cross section of the final design of the tiered wire floor system (1 - laying nests, 2 - perches, 3 - wire floor, 4 - manure belt, 5 - litter, 6 - feeder, 7 - nipple drinker).

In the following a similar test is described, as well as the behavioural research which is to provide an understanding of the use of space and the occurrence of undesired behaviour as a parameter for welfare. From 1984 onwards the aim was to conclude the project with a comparative trial on a larger scale, in which special attention would be paid to the aspects of management in relation to the battery cage system. The state of affairs in this research will be discussed in Chapter 4.
3. EXPERIMENTS WITH THE TIERED WIRE FLOOR SYSTEM

3.1 Introduction

A large number of experiments have been carried out since the beginning of the research in 1980. In this research functionality of the system as regards zootechnics and welfare aspects was of main importance and time and again strong and weak points were located, adapted and tested again.

In this chapter a number of experiments will be discussed which were carried out from the moment when a prototype had been developed which was functioning reasonably well. Successively problems will be dealt with concerning the rearing period, results of zootechnical research carried out with larger testing units (about 1250 hens) and experiments aimed at the evaluation of animal welfare. Finally the experiences of a flock supervisor who worked in a similar system will be described.

3.2 Rearing period

3.2.1 Introduction

During the initial trials with this system zootechnical results proved to be highly dependent on the spreading of the hens throughout the system. The experiments in which the hens spread well were characterized by a high production, a low percentage of floor eggs and limited mortality. In other experiments however most of the hens remained on the litter, which in one case might have led to a disastrous end of the test if feed and water had not been supplied on the litter during the first weeks or the hens confined to the wire floors. After a number of experiments it was plausible that the cause of this problem was to be found in the rearing of the hens. A series of trials was started in which the influence of the rearing method, the age of the hens at housing in the tiered wire floor system and the type of hen were studied as regards their functioning in the tiered wire floor system.
3.2.2 Methods

In one of the trials small flocks of hens were reared in three different systems, that is:
- the battery cage system, the most frequently applied method in practice.
- the deep litter floor system, the traditional rearing method.
- the tiered wire floor system.

From each rearing system half of the hens was placed in identical sections of the tiered wire floor system at the age of 16 weeks and the other half at the age of 19 weeks. After that the zootechnical data in each section up to the age of 28 weeks were registered (egg production, percentage floor eggs, feed consumption, mortality), as well as locomotor activity and spreading of the hens over the system (density on the floors, laying nest preference, use of perches at night).

During the rearing period the feed consumption of the hens was restricted according to the directions of the breeder.

During the laying period the hens were fed ad libitum. In all sections the laying nests were opened up after the first egg had been laid. These experiments were carried out with white and medium weight brown laying hens.

3.2.3 Results

In figures 12a up to and including f the spreading of the hens over the different locations in the tiered wire floor system is conveyed in connection with the different rearing methods and housing ages. The space between the lines records the percentage of the hens on the litter, the feeding tiers (lower and middle tiers), the perches (top tiers) and the laying nests.

Figures 13a and b show the locomotor activity of the hens at "early" and "late" housing in the tiered wire floor system during the first weeks after housing. The locomotor activity is expressed in the number of movements from one tier (or the floor) to another per 100 hens per hour. Table 3 lists the main production characteristics for the different rearing methods and housing ages.
Figure 12 Spreading of the hens over the locations with the different rearing methods and housing ages.

a. Rearing method: twf system; housing at 16 weeks.

b. Rearing method: twf system; housing at 19 weeks.
Figure 12 c. Rearing method: battery cage system; housing at 16 weeks.

d. Rearing method: battery cage system; housing at 19 weeks.
Figure 12

e. Rearing method: deep litter floor system; housing at 16 weeks.

f. Rearing method: deep litter floor system; housing at 19 weeks.
Figure 13 Locomotor activity of the hens at "early" and "late" housing in the tiered wire floor system.

a. Housing at 16 weeks.
b. Housing at 19 weeks.

numb. jumps  
100 hens/hr

---

day (days)

---

day (days)

- twf rearing
- battery rearing
- deep litter floor rearing
Table 3 Survey of production results at "early" and "late" housing of white laying hens.

Housing at 16 weeks:

<table>
<thead>
<tr>
<th>Rearing method</th>
<th>number of eggs per hen present</th>
<th>% floor eggs 0 to 50%</th>
<th>% floor eggs 50% to age 170 days</th>
<th>feed cons. 1st week</th>
</tr>
</thead>
<tbody>
<tr>
<td>twf system</td>
<td>47.7</td>
<td>2.6</td>
<td>0.6</td>
<td>64.6</td>
</tr>
<tr>
<td>Battery cage system</td>
<td>44.5</td>
<td>5.4</td>
<td>0.7</td>
<td>19.3</td>
</tr>
<tr>
<td>Deep litter floor system</td>
<td>47.1</td>
<td>4.0</td>
<td>0.9</td>
<td>60.9</td>
</tr>
</tbody>
</table>

Housing at 19 weeks:

<table>
<thead>
<tr>
<th>Rearing method</th>
<th>number of eggs per hen present</th>
<th>% floor eggs 0 to 50%</th>
<th>% floor eggs 50% to age 170 days</th>
<th>feed cons. 1st week</th>
</tr>
</thead>
<tbody>
<tr>
<td>twf system</td>
<td>40.8</td>
<td>5.2</td>
<td>1.2</td>
<td>90.9</td>
</tr>
<tr>
<td>Battery cage system</td>
<td>36.8</td>
<td>18.5</td>
<td>4.2</td>
<td>15.6</td>
</tr>
<tr>
<td>Deep litter floor system</td>
<td>43.1</td>
<td>7.4</td>
<td>0.8</td>
<td>69.0</td>
</tr>
</tbody>
</table>
As appears from figures 12c up to and including d, the hens reared in battery cages had serious adaptation problems directly after housing in the tiered wire floor system. These hens mostly stayed on the litter floor. By taking action (providing feed and water on the litter) the hens could be kept alive. As a result of these adaptation problems the hens came into production later, did not reach a comparable peak production and produced considerably more floor eggs than hens which had been reared on deep litter or the tiered wire floor system. Only weeks after housing the cage reared hens had developed a similar spreading and activity pattern.

The housing of hens from deep litter rearing to the tiered wire floor system went quite smoothly. Both behavioural observations and production results were comparable with those of the hens which had been reared in the tiered wire floor system.

These data refer to White Leghorn hens. Identical reactions occurred with the brown hens.

From the results (see Table 3) it appears that housing of hens at the age of 19 weeks in the tiered wire floor system has a negative effect on the production as well as on the percentage of floor eggs. On account of the fact that the hens started laying at about 18 weeks the first eggs of these flocks were already found in the rearing house.

3.2.4 Conclusions

As appeared from experiments battery cage rearing is an unsuitable method for hens which are housed in the tiered wire floor system during the laying period. The housing of hens at the age of 19 instead of 16 weeks also proves to have a negative effect, especially on the percentage of floor eggs.

On the basis of these experiments rearing on part wire and litter floors proves to be a proper rearing method for the tiered wire floor system. This rearing on wire and litter however must be organized in such a way that the hens learn to bridge differences in height and get accustomed to the facilities of the tiered wire floor system. Experience shows that rearing hens on part litter floors which fulfil the following conditions will give positive results.
Pictures taken during the dark period.
a. Hens which have been reared "properly" mainly occupy the upper tiers.
b. Hens which have been reared "improperly" occupy the lower tiers and even sleep on the ground.
These conditions are:
- wire floors have been installed at least 50 cms above the litter.
- perches have been installed at different heights above the wire mesh.
- feed and water are only supplied on the wire floor.
- water is offered by means of nipple drinkers.
- the pullets are encouraged to rest on the wire floor and the perches.

3.3 Zootechnical results

3.3.1 Introduction

So far zootechnical data have been obtained from medium-sized flocks of hens that were housed in a 10 metres long tiered wire floor system during their entire laying period (see figure 10a, chapter 2.2.2). This construction in which flocks of 1250 hens could be housed at a stocking density of 20-22 hens per m² house was set up in a naturally ventilated daylight house. Both white and brown layers were tested, whereby production characteristics like laying percentage, the percentage of floor eggs, the egg weight, the percentage of cracked and broken eggs, the feed consumption and mortality were registered. These tests were also meant to answer questions about the differences with the traditional battery cage system, such as the occurrence of floor eggs, feather pecking and the maintenance of a good litter quality and the problems of disease control (esp. coccidiosis) connected with this.

On the basis of two experiments these questions will be further dealt with hereafter. These experiments were carried out with white hens and medium-weight hens of a brown egg laying strain.
3.3.2 Production figures

The figures 14a and b give a survey of the production results for the two flocks. The data in Table 4 show that productivity and the average egg weight were good and that the loss of eggs through cracking and breaking was small compared with that of the identical strains in battery cages in the random sample tests at the testing station "Nederland" at Lelystad in the same period (hatch 1983).

Table 4  Production results of white and brown hens in the tiered wire floor system.

<table>
<thead>
<tr>
<th>Housed</th>
<th>Present eggs</th>
<th>Average g feed per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>WL 1</td>
<td>262</td>
<td>285 0.78 60.43 1.74 14.8 5.7 112.5</td>
</tr>
<tr>
<td>2</td>
<td>267</td>
<td>280 - 59.90 6.30 7.9 * 113.5</td>
</tr>
<tr>
<td>MZ 1</td>
<td>284</td>
<td>305 0.63 62.44 1.21 16.5 12.1 122.2</td>
</tr>
<tr>
<td>2</td>
<td>281</td>
<td>288 - 61.70 4.40 5.2 * 118.1</td>
</tr>
</tbody>
</table>

1: Average data over 357 days.
2: Average data testing station "Nederland" at Lelystad over 360 days (hatch 1983).
*: Data not known.

Not only in this experiment but in all trials carried out so far the percentage of cracked, broken and dirty eggs is considerably lower than in the case of identical hens in battery cages. If an average of 2% floor eggs would also be considered 2nd quality then it might be assumed that on the basis of these results at least 2% more 1st quality eggs would be feasible over the entire laying period in the tiered wire floor system.
Figure 14 Survey of the production results for the two flocks.

a. white layers; b. brown layers.
The results of this experiment indicate that the percentage of floor eggs, one of the possible bottlenecks of this system, can be kept at an acceptable level. As was seen before, the rearing method and age at which the hens are housed are of considerable influence on these results. A different trial with three-metres long constructions of the tiered wire floor system showed that the type of laying nest likewise affects the percentage of floor eggs (see figure 15). The wooden laying nests with Astroturf roll-away bottoms developed at Spelderholt were more satisfactory than foreign-made wholly PVC nests.

**Figure 15** Effect of nest type on percentage floor eggs.
As was noticed before, apart from the above-mentioned experiments tests have also been carried out in smaller constructions of the tiered wire floor system (200 - 400 hens), of which the production results were registered. For research technical reasons these experiments were mostly stopped after about 40 weeks. Table 5 gives a survey of the major production results achieved in the short-term trials with the tiered wire floor system, which have been carried out up till now.

**Table 5** Results in the short-term trials with the twf system.

<table>
<thead>
<tr>
<th>Number of hens</th>
<th>Hens per m²</th>
<th>Trial period (weeks)</th>
<th>Average lay %</th>
<th>Aver. feed cons. % f.e.</th>
<th>Peak prod.</th>
<th>Weeks over 90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>3x270</td>
<td>20</td>
<td>white 17</td>
<td>77</td>
<td>101</td>
<td>0.7</td>
<td>92</td>
</tr>
<tr>
<td>3x270</td>
<td>20</td>
<td>white 16</td>
<td>76</td>
<td>103</td>
<td>2.2</td>
<td>93</td>
</tr>
<tr>
<td>1251</td>
<td>19</td>
<td>white 23</td>
<td>76</td>
<td>110</td>
<td>1.1</td>
<td>88</td>
</tr>
<tr>
<td>1407</td>
<td>19</td>
<td>white 27</td>
<td>74</td>
<td>106</td>
<td>1.1</td>
<td>86</td>
</tr>
<tr>
<td>3x270</td>
<td>20</td>
<td>white 10</td>
<td>66</td>
<td>98</td>
<td>1.3</td>
<td>90</td>
</tr>
<tr>
<td>3x270</td>
<td>20</td>
<td>brown 10</td>
<td>73</td>
<td>120</td>
<td>2.8</td>
<td>92</td>
</tr>
<tr>
<td>1225</td>
<td>19</td>
<td>white 16</td>
<td>72</td>
<td>104</td>
<td>1.4</td>
<td>91</td>
</tr>
<tr>
<td>1250</td>
<td>20</td>
<td>brown 16</td>
<td>82</td>
<td>119</td>
<td>0.7</td>
<td>94</td>
</tr>
<tr>
<td>3x270</td>
<td>19</td>
<td>white 17</td>
<td>76</td>
<td>106</td>
<td>0.5</td>
<td>93</td>
</tr>
<tr>
<td>3x270</td>
<td>19</td>
<td>white 14</td>
<td>75</td>
<td>110</td>
<td>1.3</td>
<td>93</td>
</tr>
<tr>
<td>4x360</td>
<td>20</td>
<td>white 27</td>
<td>79</td>
<td>109</td>
<td>10.7</td>
<td>94</td>
</tr>
<tr>
<td>4x408</td>
<td>20</td>
<td>white 27</td>
<td>79</td>
<td>110</td>
<td>14.4</td>
<td>95</td>
</tr>
<tr>
<td>1255</td>
<td>20</td>
<td>white 37</td>
<td>76</td>
<td>110</td>
<td>3.0</td>
<td>89</td>
</tr>
<tr>
<td>4x350</td>
<td>19</td>
<td>white 25</td>
<td>74</td>
<td>104</td>
<td>1.9</td>
<td>93</td>
</tr>
<tr>
<td>4x391</td>
<td>19</td>
<td>white 25</td>
<td>72</td>
<td>104</td>
<td>2.3</td>
<td>92</td>
</tr>
<tr>
<td>1x360</td>
<td>20</td>
<td>white 19</td>
<td>76</td>
<td>103</td>
<td>0.6</td>
<td>96</td>
</tr>
<tr>
<td>1x180</td>
<td>10</td>
<td>white 19</td>
<td>76</td>
<td>101</td>
<td>0.8</td>
<td>97</td>
</tr>
</tbody>
</table>
3.3.3 Mortality and disease control

As regards the health aspects the experiments concluded so far indicate that in the tiered wire floor system the same problems occur as in the traditional part litter floor system. Table 4 shows that the mortality percentage for the flock of white and brown hens is considerably higher as compared with the figures of the random sample test at the testing station at Lelystad. The good production per surviving hen proves that infectious diseases played no important part as a cause of the relatively high mortality, except for some cases of leucosis with the white laying hens. Mortality was highest among the brown laying hens as a result of feather pecking and cannibalism which took serious forms after the sixth month. The direct sunlight coming into the house and the pelletedized feed might be considered contributing factors.

The short-term trials with the tiered wire floor system (Table 6) also indicate that mortality in most experiments was higher than the acceptable mortality percentage of 0.5% per 4 weeks.

Table 6 Mortality percentages in 6 experiments with the tiered wire floor system.

<table>
<thead>
<tr>
<th>Exp.</th>
<th>Number at start</th>
<th>Number of periods*</th>
<th>Mortality perc.</th>
<th>Acceptable mort. %</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1619</td>
<td>5</td>
<td>4.3</td>
<td>2.5</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>2680</td>
<td>7</td>
<td>2.5</td>
<td>3.5</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>1620</td>
<td>3</td>
<td>3.0</td>
<td>1.5</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>2475</td>
<td>14</td>
<td>16.0</td>
<td>7.0</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>1620</td>
<td>4</td>
<td>3.0</td>
<td>2.0</td>
<td>+</td>
</tr>
<tr>
<td>6</td>
<td>3072</td>
<td>7</td>
<td>2.0</td>
<td>3.5</td>
<td>-</td>
</tr>
</tbody>
</table>

*Period = 4 weeks.

Table 7 registers, per experiment, the three major causes of mortality in order of importance. Leucosis and cannibalism appear to have been the most
significant causes. In the last experiment coccidiosis was the most important mortality cause. However, this experiment took place in a house in which the litter condition could not very well be kept under control.

Table 7 The three major causes of mortality per experiment in order of importance.

<table>
<thead>
<tr>
<th>Exp. number</th>
<th>1st cause</th>
<th>2nd cause</th>
<th>3rd cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>leucosis</td>
<td>cannibalism</td>
<td>peritonitis</td>
</tr>
<tr>
<td>68</td>
<td>kidney def.</td>
<td>cannibalism</td>
<td>bleeding</td>
</tr>
<tr>
<td>49</td>
<td>leucosis</td>
<td>cannibalism</td>
<td>kidney def.</td>
</tr>
<tr>
<td>388</td>
<td>cannibalism</td>
<td>leucosis</td>
<td>peritonitis</td>
</tr>
<tr>
<td>49</td>
<td>leucosis</td>
<td>unknown</td>
<td>cannibalism</td>
</tr>
<tr>
<td>67</td>
<td>coccidiosis</td>
<td>accident</td>
<td>gastroenteritis</td>
</tr>
</tbody>
</table>

Between brackets the total mortality percentage is given.

In order to gain insight into the occurrence of feather pecking in the tiered wire floor system, nowadays the feathers of the hens are checked on damages in the trials with the tiered wire floor system. This check is done when the hens are housed in the system and at the end of the trial. Hereby a random sample is taken out of the flocks. As long as the risk of feather pecking cannot be sufficiently kept under control, beak-trimming of the hens remains necessary.

Coccidiosis is a typical deep litter housing problem. In actual practice the presence of coccidia in the intestines of the hens cannot be prevented when they are floor reared. Although in the tiered wire floor system the bulk of the manure remains out of reach of the hens via the wire floors and manure belts, some manure still drops into the litter. The litter condition determines the growth of oocysts. When the litter condition is bad (wet) a continuous recontamination takes place and premunity is broken.
Because coccidiosis may be a major cause of mortality a number of measures have been taken in cooperation with the Poultry Health Service at Doorn to prevent and control coccidiosis in the tiered wire floor system. Much emphasis is put on a prewarning system about the infection pressure (oocysts per gram of fresh manure) and the controlled immunity build up in flocks during the rearing and laying period.

3.3.4 Litter and manure

Ventilation and air distribution in the house play an important part in maintaining a good litter quality during the laying period. In the naturally ventilated house with the 10 metres long tiered wire floor construction a good litter quality could be maintained. After roughly 3 months the litter in the system (a mixture of chaff and wood shavings) consisted of a mixture of decayed litter and dry manure, a highly absorbent substance. Only about 25% of the produced manure falls into the litter, as can be seen in Table 8; the remainder is removed via the manure belts.

Table 8 Distribution of manure* (kg dm and %) over tiers and litter in tiered wire floor constructions with two types of laying hens (white and brown).

<table>
<thead>
<tr>
<th>Location</th>
<th>WHITE</th>
<th>BROWN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg dm**</td>
<td>%</td>
</tr>
<tr>
<td>Upper tier</td>
<td>304.2</td>
<td>29.1</td>
</tr>
<tr>
<td>Middle tier</td>
<td>238.8</td>
<td>22.8</td>
</tr>
<tr>
<td>Lower tier</td>
<td>224.0</td>
<td>21.4</td>
</tr>
<tr>
<td>Total manure belt</td>
<td>767.0</td>
<td>73.3</td>
</tr>
<tr>
<td>Litter</td>
<td>279.4</td>
<td>26.7</td>
</tr>
</tbody>
</table>

* The calculation of the total amount of produced manure was based on the feed consumption: amount of manure (g, 20% dm) = 1.2 x amount of feed (g).
** Each figure is the sum of 11 monthly weighs of the total manure production on all manure belts and the dm analysis of one sample per tier.
3.3.5 **Conclusions**

The trials which have been conducted so far in the tiered wire floor system seem to make feasible a good production with a low percentage of floor eggs, provided that a number of conditions will be fulfilled. Due attention should be given to the quality of the litter, also for reasons of disease prevention. All results have been obtained from small- and medium-scale experiments (300 - 400 and ± 1250 hens respectively). Future research on a semi-practical scale will have to prove how larger flocks of hens will perform in the tiered wire floor system.

3.4 **Behaviour**

3.4.1 **Introduction**

The aim of behavioural research is to answer questions concerning the use of space and the installed facilities (litter, perches, laying nests) and the welfare of the hens in this system. In the first research stage the use of space was mainly studied by measuring the spreading and locomotor activity of the hens throughout the system. In trials which have recently been concluded the emphasis was shifted to the use of the other applied facilities. In this respect a study was made whether it would be possible to make the hens use certain facilities in the system more intensively during certain periods of the day by lighting these parts and so making them more attractive for the hens. In current trials the influence of the stocking density on the spreading and behaviour of the hens in the system is being studied. Behavioural observations are carried out in smaller units with a length of three metres. The size of the flock varies between 200 and 400 birds, depending on the desired housing density. The birds are always observed from the outside of the system. Behavioural observations are concerned both with the entire flock (so-called group observations) and individual hens (so-called individual observations) in the system.
3.4.2 Spreading of the hens over the system

The spreading of the hens over the system and the use of the various facilities has been measured on the basis of location counts. In a location count the number of hens on different locations is counted (ground, lower tiers, middle tiers, perches, laying nests). At the same time some activities are registered according to the number of hens that are sitting, feeding, drinking or dustbathing, in order to get a simultaneous impression of the behaviour of the hens on the locations.

In one of these experiments these observations were carried out in two sets of four similar units in which the floors had a width of 1.30 (narrow) or 1.70 m (wide). The housing density in all units was 20 hens per m² floor space. During the first 11 weeks after housing in the system (at the age of 19 weeks) the hens of each unit were observed one day per week between 9.00 and 10.30 hrs and 15.15 and 16.45 hrs. Figure 16 shows the results of the observations in the units with the narrow floors. The average number of hens per location per week is represented as percentage of the total number of hens present.

It is obvious that the birds prefer to remain on the ground during the first weeks. The longer the hens have been in the system the more intensively the tiers are used and approximately three weeks after housing the spreading has stabilized (32% on the ground, 25% on the lower tiers, 22% on the middle tiers and 15% on the top tiers), providing that the hens have been well reared. The width of the tiers proves to be of little influence on the spreading of the hens over the system.
Figure 16 Percentages of the total number of hens present on the different locations during the first weeks after housing in the units with the narrow floors (at the age of 19 weeks).
Although these data are based on spot checks carried out at two times of the day, the registered spreading appears to be a reasonable reflection of the average spreading throughout the day. In a similar unit the number of birds at different locations was counted once every 15 minutes during the entire photoperiod. This count showed that on average 32% of the hens stayed on the ground, 25% on the lower tiers, 22% on the middle tiers and 12% on the top tiers. This corresponds well with the spreading on the basis of two spot checks a day. During the night the spreading is obviously totally different. Then practically all birds are on the tiers, the top tiers being occupied most intensively.

3.4.3 Locomotor activity of the hens in the system

The locomotor activity of the hens (the frequency and the pattern of the movements from one position to another) has been measured by means of movement observations. During such an observation all movements were recorded on a tape recorder during 15 minutes per service aisle (between laying nest and tier construction, tier construction and tier construction). These observations have been carried out at least once in all experiments done so far, because together with the data on the spreading of the hens they form an important criterion (especially when the hens have not been in the system for long) in giving information on the extent to which the birds have adapted to the system.

The fact is that from observations it appeared that, when there was a case of disproportionate spreading over the system and relatively few movements just after housing, this was accompanied by a relatively high mortality, a high percentage of floor eggs and a lower production. This phenomenon, among other things, was seen when the birds were housed in the system too late (at the age of 19 weeks or older) or when they had been reared in battery cages.

The frequency in which movements between the locations occur, gives an impression of the way in which the hens spread throughout the system.
Figure 17 shows this. The data are based on an experiment in which observations on locomotor activity were carried out once a week in the morning from 10.30 to 12.00 hrs in four similar units with the tiered wire floor system during the first 11 weeks after housing. These observations showed clearly that the hens made use of the differences in height between the tiers of both constructions to move up or down in the system.

Observations of individual hens in the system showed that they were spotted on different locations throughout the system. By distinguishing nine positions (six tiers, ground, nests on both sides) it appeared that three quarters of the hens were registered on five or more different positions.

3.4.4 Use of facilities

The location counts which were carried out during the whole light period give an overall impression of the use of the provided facilities, apart from the spreading of the flock throughout the system. Observations of individual birds offer more information on the time spent on various forms of behaviour, the frequency of certain short-term forms of behaviour and the length of time a hen spends on average on the different locations of the system.

Group observations

- Perches
The perches located on the top tiers of the system are used intensively by the hens, particularly at night. Some observations during this period showed that, if they have been reared properly almost all hens sleep on the perches or in case of lack of room on the perches on both sides of the middle and lower tiers.
Figure 17 The way in which the hens change position in the tiered wire floor system (the thickness of the arrows stands for the frequency).
From location counts, carried out during the entire light period, it appeared that on average 15% of the hens were registered on the perches, the percentage in the period from 12.00 to 15.00 hrs being about 25%. On average 40% of these hens were observed to be sitting.

- Laying nests

The percentage of floor eggs together with total egg production form a good indication of the extent to which a flock of hens makes use of the laying nests. The percentage of floor eggs should be less than 2%. On the basis of location counts carried out with intervals of 30 minutes during the entire light period on two consecutive days in two similar units with tiered wire floor systems it appeared that the nests were used intensively until 12.00 hrs. The hens registered near the laying nests during the second half of the light period were sitting or standing more often on the alighting rails in front of the laying nests. In all experiments with the tiered wire floor system carried out so far it appears that the hens have a slight preference for the laying nests located on the side of the highest tier block. On both positions of laying nests more eggs are laid in the top row (about 60% top to 40% on lower rows).

- Litter

Approximately 30-35% of the hens in the system are found on the litter during the light period. These data however are based on observations in which the number of birds on the litter was calculated as remainder. In one experiment the number of hens on the litter was counted at 15 minutes intervals throughout the entire light period. For this purpose the litter had been divided into 10 imaginary sections.

Apart from the total number of hens there was also a registration of the number of hens showing one of the following forms of behaviour, that is: pecking and scratching, object pecking, feather pecking, preening, resting, standing, dustbathing. In Table 9 the results of these observations are shown. Next to the average percentage over the light period (5.00 - 19.00 hrs) a distinction is made between the first and the second half of the light period.
Table 9 Results from floor observations.

<table>
<thead>
<tr>
<th></th>
<th>5.00-12.00 hrs</th>
<th>12.00-19.00 hrs</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present*</td>
<td>22.1</td>
<td>29.8</td>
<td>26.0</td>
</tr>
<tr>
<td>Pecking and scratching**</td>
<td>16.6</td>
<td>32.3</td>
<td>24.5</td>
</tr>
<tr>
<td>Object and feather pecking**</td>
<td>5.3</td>
<td>9.7</td>
<td>7.5</td>
</tr>
<tr>
<td>Preening**</td>
<td>17.3</td>
<td>8.9</td>
<td>13.1</td>
</tr>
<tr>
<td>Resting**</td>
<td>10.2</td>
<td>3.9</td>
<td>7.1</td>
</tr>
<tr>
<td>Dustbathing**</td>
<td>6.6</td>
<td>11.0</td>
<td>8.8</td>
</tr>
</tbody>
</table>

* Expressed as percentage of total number of hens in the system.
** Expressed as percentage of total number of hens on the litter.

When the hens on the litter were counted it appeared that on average 5% fewer hens were found on the litter than when this percentage was calculated as remainder. This difference can be explained from the fact that observation errors of all counts accumulate in this remainder. The occupation of the litter is lower in the morning than in the afternoon, which is connected with the moment of egg laying, which takes place mainly in the morning.

The behaviour of the hens on the litter moreover differs between the morning and the afternoon. Whereas almost 30% of the hens is seen preening or resting in the morning, during the afternoon there is more emphasis on pecking and scratching, pecking at wire, timberwork or the legs of the tier constructions (object pecking). In the course of the dustbathing a clear peak could be discerned (see figure 18).

- Feeding floors
On average 20 to 25% of the hens in the system were found on the lower and middle tiers (feeding tiers). From experiments in which location counts were made during the entire photo period it appeared that this percentage remains rather constant during the day. On average 37% of the hens are feeding.
In one unit with the tiered wire floor system 10 hens from the flock were individually marked and observed for twenty minutes during each of three periods of the day (8.00 - 9.00 hrs, 12.00 - 13.00 hrs, 16.00 - 17.00 hrs). Hereby both length of time spent at the locations and the behaviour performed at the different locations were registered. The results of these observations are given in Table 10. The data of the 10 hens (over three observation periods) have been averaged.
Table 10 Results of individual observations. Data are the average of 10 hens observed individually during three periods of the photoperiod.

<table>
<thead>
<tr>
<th>Behaviour**</th>
<th>Dust</th>
<th>feather</th>
<th>object</th>
<th>floor</th>
</tr>
</thead>
<tbody>
<tr>
<td>% time*</td>
<td>bath</td>
<td>preening</td>
<td>resting</td>
<td>pecking</td>
</tr>
<tr>
<td>Litter</td>
<td>18.0</td>
<td>2.8</td>
<td>7.9</td>
<td>13.5</td>
</tr>
<tr>
<td>Lower tiers</td>
<td>22.9</td>
<td>2.3</td>
<td>1.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Middle tiers</td>
<td>24.7</td>
<td>4.1</td>
<td>1.6</td>
<td>2.1</td>
</tr>
<tr>
<td>Perches</td>
<td>19.6</td>
<td>27.2</td>
<td>36.1</td>
<td>5.8</td>
</tr>
<tr>
<td>Laying nests</td>
<td>12.9</td>
<td>0.8</td>
<td>23.2</td>
<td>1.6</td>
</tr>
</tbody>
</table>

* Percentage of total observation time.

** Percentage of time spent on respective locations.

The hens prove to spread their time rather evenly over the various locations. Almost a third of the time the hens are on the litter they spend pecking and scratching. On the feeding tiers the hens are feeding approximately 33.5% of the time. On the perches the hens are resting or preening during more than half of the time spent on this location.

In two experiments the dustbathing behaviour of the hens has been studied more accurately by registering the frequency and/or duration of the separate dustbathing routines of individual dustbaths between 11.00 and 14.00 hrs. It appeared from these observations that there are large differences in the duration of the individual dustbaths. A distinction could be made between dustbaths shorter and longer than 6 minutes (short and long dustbaths). A quarter of the individual dustbaths took less than 6 minutes. The short dustbaths were characterized by the absence of one or more dustbathing routines, whereas also the frequency/duration of other components was clearly lower/shorter than in long dustbaths. Similar long and short dustbaths have also been observed in other studies and are therefore not specifically caused by the system. Figure 19 shows the structure of a long and short dustbath. The frequency/duration of the
separate dustbathing components has been marked off per minute (short dustbath) or per 5 minutes (long dustbath) against the duration of the dustbath.

During a short dustbath the hen does not do much more than vertical wing-shaking and bill-raking, after which the dustbath is finished. The long dustbath gives a good impression of the way in which a "normal" dustbath is taken.

3.4.5 Possibilities of attracting the hens to the litter by means of a lighting system during part of the photo period

An experiment has been carried out to see whether it would be possible to have the litter being used more intensively by the hens during part of the photo period. In a unit with the tiered wire floor system (housing density 20 hens per m² floor surface) the litter was lit between 12.00 and 17.00 hrs. During the entire light period (5.00 - 19.00 hrs) location and ground observations were made at 15 minutes' intervals with and without the litter being lit. The results of the location observations are shown in figure 20.

The numbers of hens per location are shown as a percentage of the total number of hens present. It is clear that the hens are more attracted to the litter when this is lit. The hens even seem to anticipate this. However, from the results of the ground observations, listed in Table 11, the lighting of the litter does not seem to have a positive influence on the behaviour of the hens. Most pecking and scratching activities appear to occur after turning off the light on the litter (after 17.00 h), while in the period from 12.00 to 17.00 hrs less desirable behaviour like object and feather pecking occurs. Also in this period more hens can be seen resting on the litter, which is less desirable because of unnecessary fouling of the litter by manure.
Figure 19 Structure of a short (a) and a long (b) dustbath.
Figure 20 Influence of light on the litter between 12.00 and 17.00 hrs on the spreading of the hens over the various locations in the system.

% hens

- Penches
- Middle tiers
- Lower tiers
- Litter

--- light
--- no light
Table 11 Influence of light on the litter between 12.00 and 17.00 hrs on the behaviour of hens on the ground ("no": counts done when the litter was not lit; "yes": counts done when the litter was lit from 12.00 to 17.00 hrs).

<table>
<thead>
<tr>
<th></th>
<th>5.00-12.00 hrs</th>
<th>12.00-17.00 hrs</th>
<th>17.00-19.00 hrs</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present*</td>
<td>22.1</td>
<td>19.2</td>
<td>29.8</td>
<td>42.5</td>
</tr>
<tr>
<td>Pecking and</td>
<td>16.7</td>
<td>18.7</td>
<td>26.5</td>
<td>29.5</td>
</tr>
<tr>
<td>scratching**</td>
<td>5.3</td>
<td>4.2</td>
<td>8.9</td>
<td>12.9</td>
</tr>
<tr>
<td>Object and</td>
<td>17.3</td>
<td>17.3</td>
<td>10.3</td>
<td>9.3</td>
</tr>
<tr>
<td>Feather pecking**</td>
<td>10.2</td>
<td>27.3</td>
<td>4.7</td>
<td>6.5</td>
</tr>
<tr>
<td>Preening**</td>
<td>6.6</td>
<td>3.5</td>
<td>15.1</td>
<td>10.6</td>
</tr>
<tr>
<td>Resting**</td>
<td>16.1</td>
<td>5.6</td>
<td>5.2</td>
<td>5.4</td>
</tr>
<tr>
<td>Dustbathing**</td>
<td>27.8</td>
<td>23.3</td>
<td>29.4</td>
<td>25.7</td>
</tr>
</tbody>
</table>

* Expressed as percentage of the total number of hens in the system.
** Expressed as percentage of the number of hens on the litter.

3.4.6 Conclusions

From the results so far it can be concluded that the hens in the tiered wire floor system make good use of the available facilities:
- the hens properly and easily use the whole system.
- perches and laying nests are well used for the behaviour for which they are intended, i.e. resting/preening and egg laying.
- the litter is used intensively for pecking and scratching and dustbathing. Dustbathing is performed "normally".
In terms of welfare this is a significant improvement on the battery cage. Current and future research will have to reveal any possible bottlenecks and the way to solve these. Hereby the tiered wire floor system will also be compared with other systems.
Because of the fact that the hens have laying nests at their disposal they can remain on the nests when they are broody. To prevent the hens from getting broody it is recommended to shut the laying nests at the end of the light period. Hens that are still on the nests must be removed. In the course of the dark period the nests must be re-opened so that they will be available again in the morning. An additional advantage of this method is that the nests cannot be used as a sleeping place, thus preventing contamination with manure.

3.5.3 Collecting floor eggs

The availability of laying nests provokes a risk of the occurrence of floor eggs. On developing this system due attention was paid to this matter and a number of measures were taken to keep the percentage of floor eggs at an acceptable level (proper laying nest, sufficient laying nests, early housing of the hens in the system, opening of the laying nests only after the first egg has been laid). Yet there are hens that prefer laying their eggs in the litter or on the tiers. By maintaining enough room under the lower tiers, the litter eggs can be collected without the attendant having to go on all fours.

3.5.4 Supervision of feed and water

Feed and water are supplied on the lower and middle tiers. The supervision of the feed level and the functioning of the nipple drinkers is made easier by creating sufficient scope in the service aisles and installing lighting at tier level. A system of pan-feeders is preferable to the use of a chain trough. Not only do the pan-feeders facilitate the passage of the hens on the tiers, but it will also be easier to check the feed level because of their larger width.
3.5.5 Activities at the beginning and end of the laying period

Quite some work goes into the transportation of the litter into the system at the beginning of the laying period. At housing time the hens are placed on the tiers. This is an easy job. Catching the hens at the end of the laying period requires more labour. Contrary to what is often thought the tiers hereby present no special obstacle. Only catching the last hens may take some extra time. It is preferable to catch the hens in the dark. Eventually the work is facilitated by installing blue lights in the system, thus giving the catchers a better view on the hens.

On cleaning the system the litter is removed, which can only be partly mechanized. Here also the importance of maintaining a good litter quality emerges. When the litter is well dry and loose it can be fairly easily scooped upon the manure belts and mechanically removed from the house. For this purpose it is advisable to make the wire floors on the lower tiers partly removable.

3.5.6 Disease prevention activities

The presence of woodwork (perches and laying nests) in the system brings along the risk of lice (Northern fowl mite). These locations in the system should be regularly checked for the presence of these parasites. Furthermore the usual general hygienic precautions must be taken, such as wearing clean and disinfected shoes and clothing.

3.5.7 Conclusion

Summarizing it may be said that the care for hens in a tiered wire floor system probably will require extra labour compared to cage housing owing to the occurrence of floor eggs and the removal of the hens and the litter at the end of the laying period. The supervision of the hens will probably also take more time. In a system like this the managerial talents of the poultry farmer may have to play a more important role than in the battery cage system. However, the fact that the hens need more intensive care will turn working in the tiered wire floor system into a challenge for the motivated poultry farmer.
4. COMPARATIVE RESEARCH ON A SEMI-PRACTICAL SCALE

4.1 Introduction

As was already indicated in chapter 2 the project is now in the testing stage. The assessment of the welfare of the hens in the tiered wire floor system forms part of this stage. In this respect a start has already been made by the behavioural research, as described in chapter 3.4. This type of research is still being continued. The comparison of the tiered wire floor system with an existing system of accredited efficiency, i.e. the battery cage system, forms another part of this testing stage. A comparison was decided upon between the tiered wire floor system, as has been crystallized out after the trials of many prototypes, with the battery cages of a popular brand. For the realization of this last part a new house was constructed with two units in which the two systems can be compared on a semi-practical scale. The capacity of the house, the number of hens per $m^2$ floor space, the climate and the systems of mechanization and manure treatment are of equal level in both systems.

The major research objectives in the comparative research can be thus formulated:

- an accurate estimation, if possible, of the difference in cost price of eggs produced in the tiered wire floor system and the three-tier cage battery with a comparable mechanization.
- assessment of the maximum number of laying hens on the tiered wire floor system per one unit manpower.
- assessment of zootechnical and labour technical differences between both systems and the tracing of bottlenecks or managerial insecurities of the tiered wire floor system.

For the experimental house the usual width of 14 m was taken as a basis, the length of a testing unit is 23 m, sufficiently representative for a practical house (see figure 21). Per unit 6500 hens are housed.

On the one side of the house 6 rows of three-tier battery cages are installed (see figure 22). Although four-tier batteries are applied more often, a three-tier construction was chosen here in order to reach a housing density of ± 20 hens per $m^2$ comparable to the tiered wire floor system.
Figure 21 Plan of the new experimental house.
Figure 22 Cross section of the experimental unit with 3-tier battery cages.
Thus it is to be expected that the house climate in both experimental units will be approximately the same. As regards the farm economic results an extrapolation to a 4-tier battery could possibly be made.

In the other half of the house a tiered wire floor system was installed with four constructions of three tiers each (see figure 23). These units are separated by a service room with an observation/registration room on top (figure 24).

4.2 Technical description of the house

4.2.1 Constructional description

4.2.1.1 Understructure

In the design of the experimental house an understructure was decided upon made of a concrete floor cast in situ with a frost ridge on the outside wall. This frost ridge was provided with a constructive reinforcement to support the weight of the superstructure.

The floor is composed of 12 cm concrete with a reinforcing mesh to absorb shrinking stress. The floor is made monolithic, finished by mechanical sanding. The manure channels and pits consist of concrete floors and brick walls.

4.2.1.2 Superstructure

The superstructure is supported by 12 3-hinge laminated timber frames with a span of 14.16 m and with a distance of 4.6 m centre on centre.

In each of the sections between these frames eight purlins were applied. The lower purlin was made of wood, the other of steel (omega profile). The side walls of the house and the wall of the disinfection room consist of sandwich panels. These panels are constructed of 2 x 0.6 mm steel sheet enclosing 80 mm polystyrene foam.

The panels were finished on both sides with 200 mu plastisol coating. The ventilation valves consist of the same panels as the side walls.
The new experimental house.
Figure 23: Cross section of the experimental unit with the tiered wire floor system.
Figure 24 Cross section of the service room and observation and registration room.
The roof and house front and back also consist of sandwich panels with the following construction:
- a steel sheet piling profile with plastisol coating.
- 80 mm polystyrene foam.
- a flat steelsheet with an aluzinc top coating.
These panels are available in such lengths that they can be applied in one length from the ridge to the edge of the roof. Another advantage of these panels is that they are very stiff, and therefore fewer purlins are needed. This gives a reduction in labour in the construction at the building site. This choice was made in order to acquire experience with the application of these panels for the insulation of industrial premises. All panels were mounted with selfdrilling screws.
The inner walls consist of wooden posts and layers with multiplex sheeting on the side of the service room and on the side of the birdpen with asbestos sheets.
The floor of the observation-registration room is constructed of timber beams with multiplex floor sheets (underlayment).
The timber outside doors (battened doors) have been insulated so that they are comparable to the wall and roof panels as far as thermal insulation is concerned. On the inside they are panelled with multiplex. The inside doors consist of 40 mm multiplex.
The eaves, edges and ridges were finished by means of folbed steelsheet finished with a plastisol coating.
Next to the house on the same level as the service room there are two 12 ton feed silos.

4.2.2 Technical installations

4.2.2.1 Electrotechnical facilities

Power points for electric facilities were installed for:
- manure disposal
- egg transportation
- feed transportation
- ventilation valves
- manure dehydration systems.
The wall sockets installed in the building serve o.a. for the connection of:
- cleaning equipment
- ventilators
- feed weighing
- measuring equipment.

The bird units have the following lighting system:
In each bird unit working lights were installed. They consist of four rows of fluorescent tubes (with dimmers) to be used by the attendant when working in the house.

The main lighting system is the lighting in the bird units, necessary for optimal production and in the tiered wire floor system for a proper spreading of the hens. In the tiered wire floor system this lighting consists of 6 rows of fluorescent tubes (with dimmers), mounted vertically. In the battery cage system the experimental lighting consists of 7 rows of fluorescent tubes (with dimmers).
Finally the bird units have a twilight installation, consisting of two PL-fittings. This enables the attendant to inspect the units at night, if necessary.

4.2.2.2 Ventilation/dehydration of manure

The climate in the bird units is regulated by means of a computer controlled ventilation system.
Air is blown on the belt of each tier and as a result of this predehydration takes place. The air brought into the house through this system is at the same time considered to be the minimum of ventilation. In summer this air is supplied directly from outside, in winter it is preheated by means of a heat exchanger.

The house is ventilated moreover by means of five ventilators in the ridge and a direct air inlet in the side walls. The size of this inlet is regulated by ventilation valves. The valves are operated by servomotors. In order to neutralize the influence of wind pressure from the outside a wind pressure shield was installed on the outside along the air inlets.
4.2.3 Layout

4.2.3.1 The battery cage unit

The layout of this unit consists of 6 rows of 3-tier belt batteries (see figure 22). These are provided with a manure dehydration installation, a feeding belt, an egg collection belt with a vertically moveable cross-conveyor and a manure removal belt under the cage tiers. By means of a cross-conveyor belt placed in a channel the manure is carried out of the house and dumped on a cart via a sloping conveyor belt. The size of the cages is 0.5 x 0.5 m giving room to five hens.

4.2.3.2 The tiered wire floor unit

The layout consists of four tier constructions with three tiers each (see figure 23 and 25). The tier floor consists of a wire frame and has a width of 1.5 m. Feed supply takes place on the two lower tiers by means of a pipe feeding system with feeding pans. Nipple drinkers are likewise only applied on the two lower tiers of each construction. The upper tiers are exclusively provided with perches.

The tier constructions are made of a steel frame and installed in two side by side separated by an aisle of 70 cm wide. The floors have mutually alternating heights (see figure 23).

There are perches along the sides of the tiers. The rows of laying nests have been distributed:
- along both side walls one row, two layers.
- in the middle of the house a double row, three layers.

The nests are made of ply wood. The roll-away bottom is covered with astroturf artificial grass. The eggs land on a collection belt at the back of the nests. The perches in front of the nests can be folded up to the effect that the nests are closed. The floor of the house is covered with a layer of litter.

The manure of each tier is removed by means of a manure belt under the wire floors in the same manner as in the battery cage unit. Just as in the battery cage unit the manure belt is provided with an air drying system.
Figure 25 Detailed drawing of tier construction.
This report gives an account of the results achieved so far in a research project aimed at the development of an alternative for the battery cage system. IMAG at Wageningen and Spelderholt at Beekbergen cooperated in this project. The aim is to develop a housing system in which the welfare of the hens is better than in the battery cage and which can be commercially competitive with that same battery cage. The starting-point in this project is an alternative on the basis of deep litter housing. At the start of the project the possibilities of alternative cages had already been studied in another context.

After preliminary research in which the feasibility of the project, the financing, and the plan of action were dealt with, a design stage followed. In this stage prototypes were developed and tested during short periods. On the basis of such tests the design was discarded or adapted. After adaptation another testing took place etc.

This procedure resulted in the realization of a prototype which offered certain possibilities, the so-called tiered wire floor system.

A large number of experiments on a relatively limited scale have been carried out with the tiered wire floor system. The results of these experiments are recorded in this report. Both zootechnical results and the findings of behavioural research are dealt with. Each of them gives cause for optimism concerning the future possibilities of this system.

More information needs to be acquired as regards zootechnical, labour technical and farm economic aspects of the project. Therefore an experiment on a semi-practical scale has been decided upon, in which the tiered wire floor system is compared with the battery cage system. This proposed research is discussed in the last chapter of the report including a description of the accommodation newly built for this research.
REPORTS AND LITERATURE PUBLISHED WITHIN THE FRAMEWORK OF THE PROJECT


