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Evaluation of the Production of Grandparent Flock Keeping on Deep Litter with Different Technologies

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List of abbreviations

Abbreviation	Meaning
ad lib	ad libitum
BW	Body weight
Cum.	Cumulative
EU	European Union
FCR	Feed Conversion Ratio
GGP	Great Grandparent
GP	Grandparent
H_no	House/barn number
Kg	Kilogram
KSH	Központi Statisztikai Hivatal (Hungarian Central Statistical Office)
LEDs	Light-Emitting Diodes
No.	Number
PLF	Precision Livestock Farming
RSPCA	Royal Society for the Prevention of Cruelty to Animals
spp.	Species (plural)
Tech	Technology
UK	United Kingdom
USA	United States of America
Wk.	Week

CHAPTER 1.
Introduction

Farming has changed a great deal in the last 50 years, a fact that stands for every department. The increase in the world's population has built pressures on the agricultural sector in ways inconceivable in the 1970s. As the world's most consumed meat, the broiler meat sector represent 57% of the 1.7 billion live poultry in the EU (Eurostat, 2021), and so it is these at the forefront of these changes. Today, the production of broiler meat must be cheaper, faster, higher quality, better for the animal's welfare and more environmentally friendly – a seemingly impossible task, but one that in a fast-changing world is essential in order to keep up with competition and satisfy ever-changing legislation. A great deal of research and development has been invested into these principles by modernising farms, equipment, and techniques. This thesis aims to continue this research by investigating the effect on how these modern methods have impacted on the productivity of grandparent broiler flocks using deep litter. This thesis aims to find how efficient modern grandparent flock farming is and how its efficiency has changed in the last 50 years.

CHAPTER 2

Literature Review

The poultry market is divided into meat and egg production. The meat production sector contains the breeders and the end-product broilers, and to produce these birds, breeder flocks are also utilised which will be the focus subject of this thesis. The focus is on the modernisation of poultry technologies in the last 50 years.

2.1. Housing technologies for Layer flocks

As the name suggests, layers are birds which produce the table eggs which we eat. These birds have been 'designed' to produce eggs for human consumption with high efficiency and quality. Industry of table eggs varies across the world depending on economic and cultural factors. Data from the past 2 years shows the following production data:

- Hungary: 2.54 billion eggs in 2020 (Hungarian Central Statistical Office (KSH), 2021)
- United Kingdom: 11.3 billion eggs in 2021 (Egg info, n.d.)
- European Union: 6.7 million tons of eggs (European Commission, n.d.a)
- USA: 95.6 billion eggs in 2021 (USDA, 2022a; Schuck-Paim et al., 2021)

Of the lines which are to be discussed, the layers have the widest range when investigating the housing systems used. These are:

- Caged systems:
    - Conventional cage/ "Battery" cage
    - Enriched cage
- Non-caged systems:
    - Free range
    - Deep litter (with or without the use of slats)
    - Alternative systems e.g., Volier/aviary

The enriched cage, or "furnished cage" system, as the name suggests involves the caging of birds in standards which are seen to be improved compared with conventional or "battery" cages. Such standards include 750cm^2 space for birds (Sandilands and Hocking, 2012), which allows for a stocking density of approximately 17-22 hens/m^2, and "stimulating enriched environments" according to Riber et al. (2017). As well as the cage, the system may include a nest box, perch and a scratching area (Sandilands and Hocking, 2012). Compared with conventional cages, the enriched cage proves to decrease the risk of disease and injury of birds, as well as showing a notably lower mortality (Lay et al., 2011).

Caged systems hold many economic advantages compared to other husbandry techniques. Notably, the production cost is significantly lower when using cages in layers (Duncan, 2001), and so it may be seen as obvious why they are a popular option around the world. Other advantages noted by Duncan include the "lower incidence of disease" amongst caged poultry farms, "better working conditions" for farm workers and "ease of management". Duncan's study doesn't mention any primary economic disadvantage to caged husbandry, however these may be balanced when discovering the ethological disadvantages included in figure 3. In the European Union, the enriched cage has been increasingly seen in recent years since the introduction of the ban of battery hen keeping in 2012 (Andrews, 2012). This is due to the welfare standards being deemed inadequate for battery hens, while some studies find that battery keeping has higher efficiency and more economic benefits (Gerzilov et al., 2012), conditions such as osteoporosis have highlighted the need for better conditions (Lay et al., 2011). Looking to the future, we will likely see the demise of the enriched cage as by 2027, there is to be a ban on the use of cages for laying hens and broilers as well as many other farmed species (European Commission, 2021).

Currently, data of caged layer use stands at:

- Hungary: 80.8% (Schuck-Paim et al., 2021)
- United Kingdom: 44.2% (Schuck-Paim et al., 2021)
- USA: 76.4% (Schuck-Paim et al., 2021)
- Australia: 76.4% (Schuck-Paim et al., 2021)
- Norway: 9% (Schuck-Paim et al., 2021)

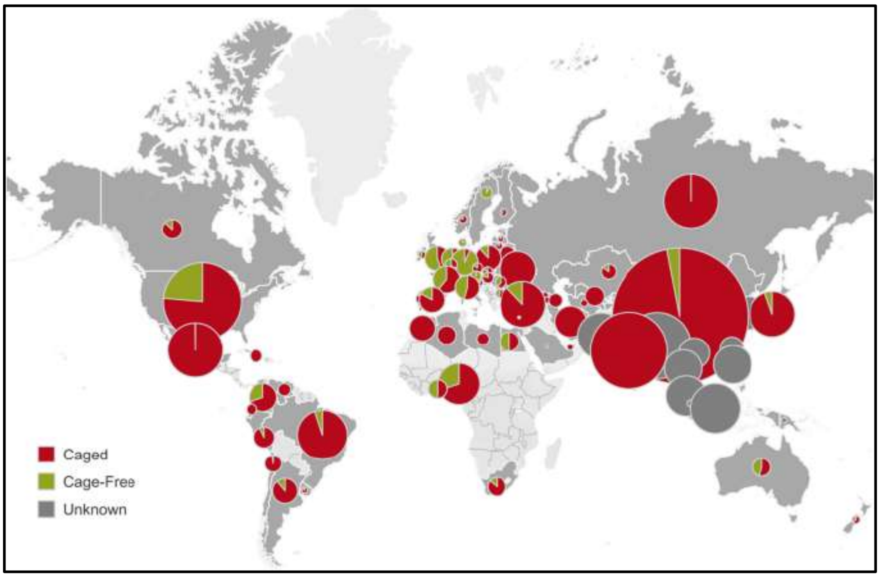

Figure 1 (above) Summary of world data of layer keeping system use (Schuck-Paim et al., 2021)

Interpreting data from Schuck-Paim et al. (2021), it appears that countries in Eastern Europe have preference for caged systems, and Western European countries, except for Spain, Portugal and France prefer the use of non-cage systems. Notably, Austria have virtually abandoned the use of caged birds in agriculture (Maertens, 2022), with their preference lying in barn/aviary use (Schuck-Paim et al., 2021). Further information by Schuck-Paim et al. (2021), including an interactive map as seen in figure 1, can be found at: https://www.hen-welfare.org/map.html and numerical data summarising the farming techniques used in the EU can also be found in figure 2.

Table 1. Layers (million) and housing (%) in the main egg producing countries of the EU in 2021

	Total number of layers	Enriched cages	Aviary	Free range	Organic
Country	Million	%	%	%	%
Germany	58,1	5,5	58,8	22,1	13,6
Poland	51,2	76,2	13,6	5	1
France*	48,3	54,1	11,7	23	11,2
Spain	47,1	73,3	16,1	9,1	1,6
Italy	40,5	35,6	54,5	4,9	4,9
Netherlands*	33,5	7,8	60,9	22,8	8,6
Portugal	10,2	75	19,5	4,7	0,8
Belgium	10,8	36,2	42,8	13,5	7,4
EU total 2021	376	44,9	35,6	12,8	6,6
EU total 2020	372,4	48	33,9	11,9	6,2
EU total 2019	365,9	49,5	32,4	11,8	6,3

* Data 2019

Figure 2 (above) A summary table from (Maertens, 2022)

Non-caged systems may be seen more frequently in the EU as we move away from cage use, and while some may find them idyllic for agriculture, there are some short fallings that should be addressed. The increased space allows for the birds to exhibit their natural behaviours. While this is good, behaviours such as cannibalism and pilling may be seen which can lead to smothering of the birds. Lay et al., (2011) noted an increase in the number of bone fractures in non-caged systems compared with caged, and this may be seen as obvious with the increased movement of birds. In terms of infection, some incidences point to non-caged systems leading to an increase of diseases (including those by parasites). This is thought to be based on how the hygienic conditions can be maintained on the farm as well as the number of birds on site (Lay et al., 2011). Although, it should be noted that in a study by Pieskus et al. (2008), conventional and enriched cages showed a similar result to aviary systems (which are non-caged), in the prevalence of *Salmonella spp.* in laying hens.

This conflict of conclusions could be due to the use of the different systems in each of the studies. Pieskus et al. (2008) continues, stating that incidences of *Salmonella spp.* prevalence can be seen in broilers in spring, and for layers in winter, spring, and autumn. Free range farming has the lowest stocking density of the systems, and partly due to this, free range farming is associated with a higher production cost. It allows hens to roam freely around the farm, allowing them to return to the hen house at night or at times of laying. The system can be either portable or stationary, with most free-range farms found in Western Europe. As an overview, we can see these data of free-range farming from Schuck-Paim et al., (2021):

- Hungary: 1.9% free range
- United Kingdom: 54.4% free range
- USA: 5.8% free range
- China: 3% free range

In countries such as the UK, over 50% of layers are from such farms. In the EU, Ireland has the highest proportion of free range layer farms (Maertens, 2022). On free range farms, the stocking density for birds aged 21 weeks or older is < 2,500/hectare at any one time according to the RSPCA (2017). Deep litter systems (floor pens) involve manure pits within a barn and may or may not include a grid system as part of the barn structure. Typically, the stocking density of deep litter is approximately 3.5 males/m^2 or 4-5 females/m^2 (Cobb, 2014). These can be used for all poultry species, with systems including certain technologies such as artificial light programs and timed feeding and water provisions. A study by Murray (1970) concluded that grandparent flocks in broiler lines, have been shown higher productivity when farmed on deep litter, when there is an increased stocking density. Deep litter may be preferred due to the decreased maintenance requirement and the decreased bird mortality, meaning that there are both economical and possibly animal welfare gains when using this system. As mentioned earlier, non-caged systems such as these may provide conditions for the prevalence of parasites, specifically the risk of worms. Further information of the advantages and disadvantages of the various systems is summarised in figure 3. Deep litter may be combined with use of slats, and the farm we are investigating is included in this system. The slats are designed to cover the manure pit, and cover between 50-60% of the floor area (Cobb, 2014), thus providing more hygienic conditions for the birds living in the barn. When compared with the conventional and enriched cages, deep litter systems were shown to have the lowest yield of eggs from hens as well as the highest mortality level (Gerzilov et al., 2012).

Aviaries/volier systems hosts a multi-tier system and is better for the welfare of the animal. The maximum stocking density defined by the EU: 9 birds/m^2 (Sandilands and Hocking, 2012), meaning that more birds can be hosted by the barn, when compared with deep litter barns.

Table 1. Synopsis of the advantages and disadvantages of housing systems for laying hens

Housing system	Advantages	Disadvantages
Conventional cages	• Low risk of diseases and infection with parasites • Comparatively low mortality • Comparatively low risk of feather pecking and cannibalism • Low risk of bumble-foot • Reduced air pollution	• Very limited available space per hen • Strict limitation of species specific normal behaviour • High risk of bone fractures resulting from osteoporosis during depopulation • Lacking ability to escape from bullying fellow hens
Furnished cages	• Low risk of diseases and infection with parasites • Comparatively low mortality • Higher space availability, especially in colony nest systems, allow fulfilment of some, not all, natural behaviour patterns • Better bone strength • Low risk of bumble-foot	• Risk of increase of feather pecking and cannibalism in non beak-trimmed groups of brown genotypes • Substantial use of perches may result in keel bone damage • Increase of dust resulting from scratch mats and litter provision • Problems of depopulation in large colony nest systems with increased risk of bone fractures
Barn systems without outdoor access	• Higher space availability enables hens to express most species specific normal behaviour patterns • Increased bone strength • Higher space availability enables submissive hens to avoid contacts with aggressive fellow hens	• High risk of parasitic diseases and infections due to contact with faeces • High risk of foot pad dermatitis resulting from wet litter • Increased risk of bone fractures through collision with perches, nests and other amenities • Highly variable risk of feather pecking and cannibalism resulting in high mortality values • Subordinate hens may have limited access to feed and water because of bullying hens • Increase of dust resulting from litter
Barn systems with outdoor access (free range systems)	• Same advantages as in barn systems without outdoor access • Ability to forage and dust bathing in range	• Same as in barn systems without outdoor access • High risk of predation • Increased risk of infections with internal parasites • High risk of introduction of highly infectious diseases through contact with wild birds

Figure 3 (above) Summary of advantages and disadvantages of the different housing systems in layers (Zootecnica, 2017).

Again, as a non-cage system, there is an increased risk of disease. Red mite is notable in volier systems, and there is increased prevalence of egg contamination and environmental dust. Though the volier system is associated with higher costs, it is predominant in Germany and in the Netherlands (Sandilands and Hocking, 2012). The data provided by Schuck-Paim et al., (2021) deep litter and aviaries with layers to form the following statistics:

- Hungary: 17.4% housed in barns/aviaries
- United Kingdom: 1.4% housed in barns/aviaries
- USA: 17.8% housed in barns/aviaries
- China: o% housed in barns/aviaries

Another factor to be mentioned would be the production period of the birds, as depending on the age, different husbandry is required.

With regards to housing, during the rearing period of layers, deep litter and cages are in use, and as they grow, they will be transferred to enriched cages, volier systems or they may be kept on deep litter. Throughout the bird's life, certain environmental factors are controlled, these include, but are not limited to:

- Ambient temperature (floor/cage)
- Light intensity
- Light availability
- Water intake
- Relative humidity
- Ventilation

2.2 Housing technologies for Broiler flocks

The broiler is what we know as the meat-producing birds and are phenotypically different to the layers, where genetic selection is to favour larger portions of muscle, particularly the breast meat. Global trends of poultry birds are increasing, with "significant" increases in England (The Poultry Site, 2007). Other statistics include:

- Hungary: 549,000 tonnes broiler meat in 2021 (EUROSTAT, 2022)
- United Kingdom: 1.8 million tonnes broiler meat in 2021 (USDA, 2022b)
- European Union: 13.4 million tonnes in 2021 (European Commission, n.d.b)
- The highest producer being Poland who produces 2.54 million tonnes (2021) (Eurostat, 2022)
- USA: 20.4 million tonnes of broiler meat in 2021 (USDA, 2022b)
- China: 14.7 million tonnes of broiler meat in 2021 (USDA, 2022b)
- World total broiler meat production in 2021: 100 million tonnes (USDA, 2022b)

As a reminder, conventional cages have been banned in the EU since 2012, and so there is no keeping of broilers in conventional cages in the EU. Rather than opting for enriched cage systems, the most popular systems worldwide are litter systems in order to promote healthy and efficient growth of meat. Within the EU, it is stated that "All chickens shall have permanent access to litter which is dry and friable on the surface" (European Council, 2007). Elsewhere, it has been suspected that countries such as Russia, China and Turkey are using caged broiler systems (World Animal Protection, 2016) note that this source has no references.

Comparing both caged and floor systems, a study by Andrews and Goodwin (1973) found that prior to 9 weeks of age, there was no difference in feed efficiency between the two systems, but at 9 weeks, it was found that caged broilers were heavier than those reared on the floor. On the face of this information, it could be seen that caged systems would be more favourable; however, the paper continues and reveals that some of those birds would suffer from breast blisters, and lead to subsequent downgrading of meat. The conditions of space management and drinking facilities are also imperative to the welfare of the birds, and these are summarised in table 1.

Table 1 (below) EU ruling for feeder space, number of drinkers and flock density during both the rearing period and production period for broilers (European Commission, 2000; European Council, 2007)

	Program	
Broiler	Rearing period	Production period
Feeder space (ad lib)	2-3 cm/bird (chain feeder) 70-100 birds per pan (40cm)	
Drinker number (ad lib)	12-22 chicks per nipple 70-100 broilers/bell drinker	
Flock density		Must not exceed 33kg/m^2*

2.3 Broiler breeding pyramid

These flocks contain the birds whose purpose is to produce fertilised eggs that will lead to the consumer lines down the generations. These may be further defined as parent flocks (which produce the broiler and layer lines for human consumptions), grandparent (GP) flocks (which produce the breeding chicks, and will be investigated in this thesis), and great grandparent (GGP) flocks which produce the grandparent chicks). At the top of the hierarchy, are the most valuable birds, the pedigree pure lines, which will produce the GGP lines. The system of broiler breeders can be seen in figure 4.

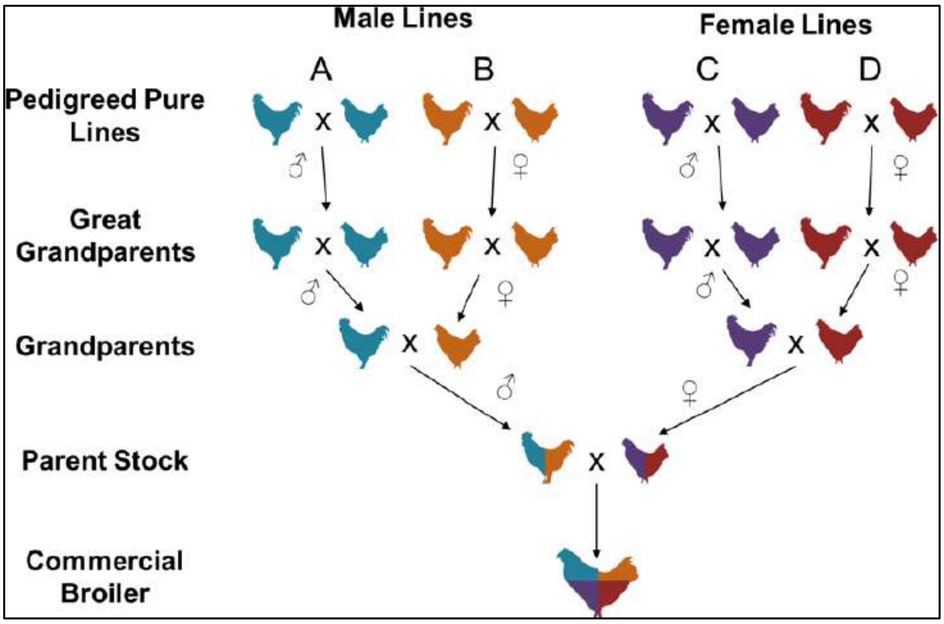

Figure 4 (above) The hierarchy of broiler breeders in commercial chicken meat production (Tarrant, 2016)

Data by the Hungarian Central Statistical Office, (2022), or "KSH" shows the number of eggs produced and "placed in incubation" to be as follows:

- GP Layer: 2.26 million
- GP Broiler: 55.52 million
- Parent layer: 24.1 million
- Parent broiler: 284.49 million

Elsewhere in the world, we see the following:

- United Kingdom: 62.4 million eggs set per month by hatcheries (UK Government, 2022)
- European Union: 50-60 million broiler breeders (Bracke et al., 2020)
- USA: 15.2 billion hatching eggs (USDA, 2022a)

Breeder flocks use either deep litter (with or without slats) or free-range systems, which have already been discussed. In the EU, some farm management factors such as stocking density of breeders are considered to be the same as those for layers and broilers in respected keeping systems (European Commission, 2012).

The European commission (2012) has made some recommendations with regards to the keeping of such breeders:

- In-house stocking rate for breeding stock shouldn't exceed 6 birds/m2
- Multilayer systems: Stocking density shouldn't exceed 9 birds/m2
- Flock size shouldn't exceed 3000 birds.

Unlike layers and broilers, breeders do not require "additional housing requirements" including, but not limited to outdoor and pasture access (European Commission, 2012).

Table 2 (below) Feeder space, number of drinkers and flock density for parent broiler breeders currently in use during both the rearing period and the production period (The Poultry Site, 2022)

	Program	
Broiler	Rearing period	Production period
Feeder space		10 cm/hen
Drinker number		8-10 birds/nipple 75 birds/bell drinker
Flock density	7 birds/m^2*	

*May increase depending on welfare standards of the farm

CHAPTER 3

Goals

This study aims to evaluate the modernisation of grandparent flock keeping on deep litter with slat in the last 50 years based on the data analysis of the daily report sheet and the production table of each houses. It is hypothesised that more recently built barns will have parameter values indicating higher productivity.

CHAPTER 4
Materials and methods

4.1 The local characteristics

The farm in this study uses deep litter with slat technology, description of this farm technology is found in the literature review. All barns on the farm use the “laying nest” from a Dutch company called “VDL Jansen”. As discussed previously, the aim of deep litter with slat is to house birds indoors with soft litter for them to walk on, with the option of adding slats to the barn to create a transition between the deep litter and the egg nest, and to separate the litter under the drinking system from the dry deep litter. The slats also allow for the easy separation of the bird’s manure from the deep litter, thus improving the hygienic conditions of the barn. The improved hygiene conditions are better for the welfare of the birds and are associated with higher productivity. As these farms have modernised, the technologies within have become more fit-for-purpose, hygienic and accurate, with added computerisation to monitor e.g., lighting programs and feeding schedules. Evolving technology for performing certain functions. The computerisation of the farm also helps this study, so we can better monitor the egg production, feed weight and number of birds in the barn. The equipment used on the farm has changed in the last 50 years.

Table 3 (below) A summary of the different houses and how they are arranged depending on the technology they use.

<table>
<tr><td rowspan="4">“E farm”</td><td>E1</td><td rowspan="3">“A technology” or “50-year-old technology” (built in 1970)</td></tr>
<tr><td>E3</td></tr>
<tr><td>E4</td></tr>
<tr><td>E5</td><td>“C technology” or “5-year-old technology” (built in 2018)</td></tr>
<tr><td rowspan="3">“T farm”</td><td>T2</td><td rowspan="3">“B technology” or “7-year-old technology” (built in 2015)</td></tr>
<tr><td>T3</td></tr>
<tr><td>T4</td></tr>
</table>

The farm contains 9 houses using the deep litter with slat system, two of which are housing the male line, named “E2” and “T1”. The houses containing the female line (which we are investigating) are arranged as shown in table 3.

4.2 Technologies on the Examined Farms

The A technology contains ~3,500 birds, which share a barn of 500m^2 floor area. The slats (seen in figure 5) in the barn cover and area of 90m^2.

Between the two slats is the egg nest, where the birds lay their eggs (figure 5 and 6). The calculated stocking density is equal to 7.00 birds/m^2.

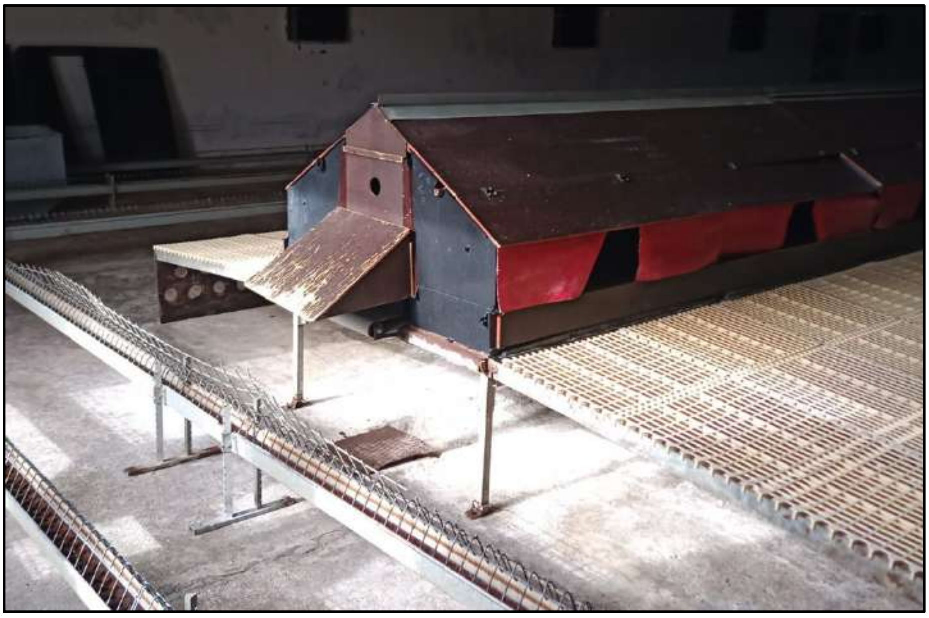

Figure 5 (above) In the centre is the egg nest where the birds will lay. To either side of the egg nest are the slats which are raised above the barn floor.

Figure 6 (above) Inside the egg nest. The bottom of the nest contains a carpet to protect the laid eggs. The eggs are then transported by egg belt to the prehall of the barn.

The cocks of the A technology group are the only group that are fed manually. Troughs (seen in figure 7) are filled by workers carrying buckets of feed. Covering an area of $44m^2$, troughs are raised so that the females cannot access them. The hens on the other hand have automatic feeders, which lead from a hopper that contains weighing scales (figure 8).
The feeders for the hens contain a grid to prevent the cocks from accessing the hens' feed. The hen feeding area is approximately $120m^2$. Each barn's silo has a capacity of 6 tonnes.

Figure 7 (above) The cock feeding troughs (wall-side) and the hen feeders (nearest).

Figure 8 (above) The feeding hopper located at the end of the egg nests for feeding the hens. Note the in-built weighing scales at the top.

The birds in the barn have water supply from 8-10 hours per day. There is a timer setup for when birds are to be given drinking water, however water is given manually, requiring human intervention to turn the water supply on. Water is provided to the birds via 300 nipple drinkers, which is the lowest number of drinkers when compared with the other technologies. Similarly, to the water supply, the lighting program in the A technology possesses a timer setup which requires a human to manually switch on or off the lights in the barn. In the barn, the birds receive 16 hours of light a day from fluorescent light bulbs. The ventilation is controlled semi-automatically, with different methods depending on the season. These are:

- Spring and Autumn: Cross ventilation
- Winter: Minimum ventilation, essentially a slightly open window (manually controlled)
- Summer: Evaporating curtains (channel ventilation) (figure 9)

Figure 9 (above) Located on the wall are the vents used for cross-ventilation and the evaporating curtain

Containing ~5,000 birds, the B technology spans an area of 780m^2 and contains slats that cover an area of 240m^2. The stocking density that can be calculated from this is slightly lower than that of A technology, equalling 6.41m^2. Both cocks and hens have automatic systems. All technology uses a separate-sex-feeding system whereby the hens are fed first by means of several chain feeders, followed by a 5-minute delay feeding the cocks. The chain feeders used by the hens run for 5 minutes, and this is repeated ever 20 minutes in order to distribute the feed equally around the barn.

The males feed from troughs which cover 84m^2 of the barn and can raise so that feed isn't available at all times. Both of these feeders are shown in figure 11. The total feeding time lasts for 1.5 hours. Between every two houses using the B technology, there is one shared silo (figure 10) which has a capacity of 16 tonnes. Because the houses share silos, workers need to sum the feed consumption data between two different houses when ordering the next delivery of feed. The lights are switched off before the troughs are raised in order to reduce cock mortalities by strangling in the cages on the troughs.

Figure 10 (above) One of this feed silos seen at the barns using the B technology

Figure 11 (above) The feeding troughs for hens (nearest) and cocks (next to the wall), note the raising cables attached to the cocks' feeding trough.

Both the drinking and lighting programs are controlled automatically by a computerised system, the preferences for the system is controlled from the screen shown in figure 12. Unlike the A technology, these settings do not require a human to enable. Like the A technology, the B technology uses fluorescent light tubes to control lighting. The B technology uses 617 nipple drinkers, which is more than double that of the A technology farms. Just like the A technology, the ventilation system used depends on the season. The A and B technologies both use minimum ventilation in winter (though the B technology is automatically controlled, unlike in the A technology) and the evaporating curtains in summer. However, in spring and autumn the B technology uses cross ventilation whereby fresh air crosses diagonally across the barn to the opposite corner where the barn air is expelled.

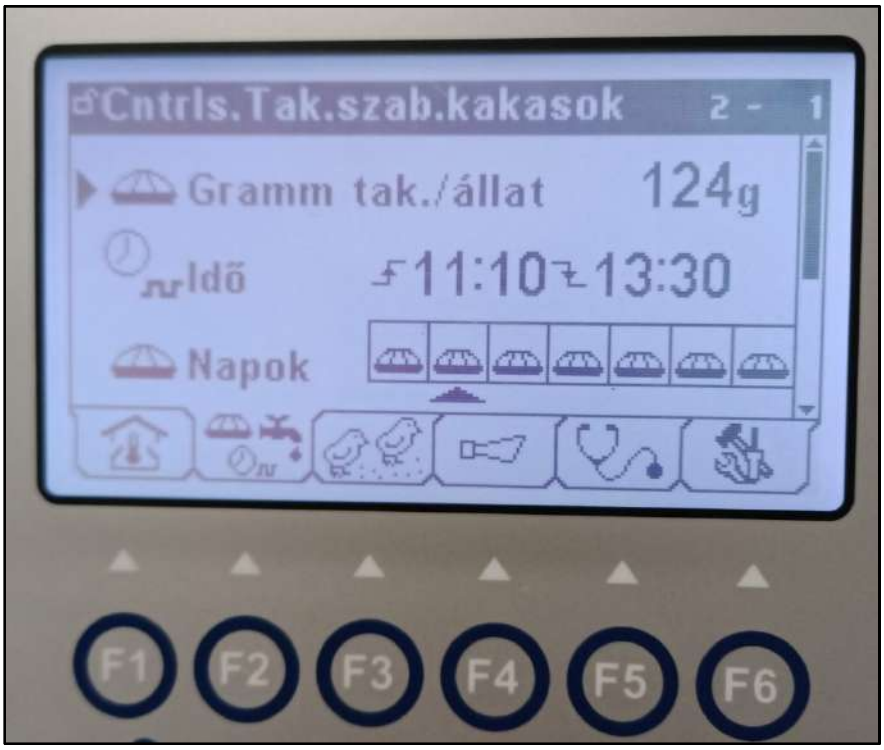

Figure 12 (above) The control panel for the barn located near the barn entrance. Here control over the weight of feed, water and light programs can be made. This particular screen is for altering the feeding settings.

The largest of the farms, the C technology houses ~ 8,000 birds in an area of 1,200m^2. This gives us a stocking density of 6.67 birds/m^2 which is not the highest nor the lowest stocking density of the 3 technologies. The slats in the E5 farm (figure 13) cover an area of 462m^2, though while this may seem a large area, relative to the total floor area on the farm, the C technology has the lowest slat area of the 3 technologies.

Figure 13 (above) The egg nest (centre) and the notably wider slats seen surrounding the egg nest.

What is unique about the feeding in this technology is that the cocks are fed using a plate feeder (figure 14). Because the slats are wider on the feeders, the hens have 4 feed lines. It can also be noted that what is also unique with this barn is that some of the hen feeders are located on top of the slats, these can be seen in figure 15. As would be expected of the largest farm, the silo capacity of the C technology is the largest of the 3 technologies with 10 tonnes capacity.

Figure 14 (above) The plate feeders used for the cocks (left) and the standard hen trough seen in the other technologies (right).

Figure 15 (above) The feeders used seen over the slatted area of the E5 farm during the service period

Again, like the B technology, the system uses automatically controlled lighting. One key difference with the E5 farm is that the lights are LEDs allowing for brightness control in the barn. The E5 farm also uses nipple drinkers, with 1178 available throughout the barn.

Table 4 (below) the parameters of each farming technology

	Farm Technology		
Parameter	A	B	C
Number of drinkers	52	617	1178
Number of nests	300	N/a	112
Feeding space (m^2)	120	378	616

The ventilation is quite different than the other technologies. The C technology utilises mixer ventilation whereby air in the barn is circulated using 2 diagonal fans to homogenize the distribution of heat in the barn (figure 16). As well as this, the barn has openable inlets to allow entry of fresh air and evaporating curtains. The key difference here is that the system uses precision livestock farming (PLF) where a computerised system can adjust the internal environment manually or automatically.

The ventilation is controlled by many technologies:

- 6 large ventilators located at the end of the barn
- 2 small ventilators on the side walls at the front and the back of the barn which allows for transition ventilation in the spring and autumn months. This functions similarly to the cross-ventilation used in the B technology

These provide "mixer ventilation", providing the desired homogenous temperature within the house. The main parameters of the houses are summarised in table 4.

Figure 16 (above) Inside a "C technology" barn. On the wall are light traps as the inner side of the evaporating curtain and the yellow inlets. The mixer ventilator is hanging from the roof.

Noting the similarities of the different farms, they are all indoors and host between 4,000-6,000 birds. Each farm has some kind of method for controlling the light, feed, ventilation and drinking water that is accessible to the birds. The differences start, however, when we delve into how these are controlled. The differences between the farms are more detailed in the previous section. But as an overview, the main difference is seen in how modern technology is utilised to control the parameters on each farm.

Each farm has benefits which in some cases are unique to the technology used:

- A technology: Computerised systems can fail. Because of the manual control, it is easier to override the system should the computer fail. Because faster cleaning and disinfection of the barn is possible, the service period of this technology is also shorter.
- B technology: Lower labour costs. Higher capacity than A technology. Monitoring of production and management data is possible in these technologies, which is beneficial to the farm owner.
- C technology: Lower labour costs. Higher capacity than A and B technologies. As with the B technology, the monitoring of production and management data is possible.

There are also notable costs and expenses seen with differing technologies:

- A technology: Because the A technology is older, it may be expected that as time progresses, the cost of upkeep and maintenance of the building and the equipment will increase, this will be considered in the economic plan of the farm. Because there is more reliability on humans to maintain the functioning of the farm, there will be increased labour costs. The A technology has a lower capacity, which is likely to coincide with a lower number of eggs produced.
- B and C technology: Chance that the technology will fail. Should the technology fail on the farm, bespoke professionals, such as engineers, electricians and programmers must be contacted. There is a basic knowledge requirement of farm workers in order to run the system, no new employees can innately understand the functioning of the farm.

4.3 Data collection and Used Parameters

During the data collection, 2 sources provided by the farm were used – farm production table and daily report table. The majority of the information, including the number of animals, the number of eggs produced, and the weight of the birds was obtained from the farm production table. Two separate spreadsheet documents were provided by the farm owner containing information from the E farm and T farm, and each document contained each of the specific barns which we were investigating on separate sheets. The **farm production tables** are essential for us to investigate the production of the farm, as the number of eggs produced, the bird weight, the feed dosage, and the number of living and dead birds are used to help us calculate the following production parameters.

These are:

- Weekly mortality
- Cumulative mortality
- Average number of eggs produced per hen per week
- Hen and cock feed conversion ratio (FCR)
- The farm production tables also highlighted the week which had the peak productivity, based on the egg production %.

The second source, the **daily report table,** contained the recorded data for each day of the production from the settlement to the slaughter for each farm. The main information obtained from these documents was the weekly amount of feed that was provided for the hens and the cocks. The feed information was used alongside data from the farm production table to calculate the FCR. The data from both sources undergo statistical analysis and will be compared as the A, B and C technology. This enables us to better assess how the productivity changes as the technology in this sector becomes more modernised.

4.4 Statistics

Egg production % values were taken directly from the Farm production table and were given for every week of production. For each barn, the highest egg production % value for the production period gave the “peak production %” value. The age at peak production value is the liveweek age of the birds when the peak production value was reached. The persistency of egg production gives the length of time (in this case in days) where the egg production % is consistent over a given threshold. For this study, a threshold of 10% below the peak production for each barn was used. The 10 % threshold is a constant deemed to be where the production is at a level similar to the peak, but over a more sustained period. To calculate persistency, first, 10% was subtracted from each of the peak production values for each respective barn e.g., where E1 farm had a peak production of 48.73 %, 10% was subtracted, so the threshold value became 38.73 %. Then to calculate the persistency, the number of days that the barn held the egg production % value of more than its 10% threshold value were counted. The sum of these for each of the barns gave the “egg production persistency” value. The total hatch egg value is simply the number of fertile eggs provided by the barn per production period. These data were collected from the Farm production table. The FCR is a recognised calculation to find the efficiency of resource input compared with product output from a system.

For this study, the input is the feed provided for the birds in a barn, and the product output is the number of hatch eggs produced by the same barn. The feed data is collected and collated in the Daily report table, from which it is manually converted into weekly summaries to ensure for better compatibility with data in the farm production table (whose data is arranged weekly). The summed number of hatch eggs produced in the production period is divided by the total mass of feed (kg) provided to the same barn to give the FCR:

$$FCR = \frac{Total\ no. hatch\ eggs\ from\ barn}{Total\ mass\ of\ feed\ (kg)\ into\ barn}$$

Rather than using the raw mortality data, the cumulative mortality uses the original number of birds at the start as a baseline. Data are provided for hens and cocks as separate groups.
It should be noted that raw mortality data from E1, E3, E4, E5 and T2 showed an increase in bird numbers after the start of the production period, resulting in a negative mortality value. This was due to “spiking” males whereby younger males are introduced to the aforementioned flocks in order to prolong and increase the hatchability using the social ranking in the flock. The age and body weight at 5% Production are simply the liveweek age and the average bodyweight of birds in the barn where the egg production % value reaches 5%. The age and body weight at peak production values are the liveweek age and average bodyweight of birds in the barn where the egg production % value reaches its highest value for the production period. To find the age and body weight of the birds at slaughter, data from the Daily report table is used, the date that birds are first selected for slaughter is assigned the corresponding liveweek age and this then marks the slaughter age. The average bodyweight during the same week is the slaughter bodyweight.
The feed consumption (kg)/100 eggs is calculated as follows:

$$\frac{Total\ feed\ (kg)}{Total\ no. hatch\ eggs\ \div 100}$$

The total feed value is the sum of all feed given to each barn for hens only during the production period. Raw data of the production days was provided by the farm. Comparative statistics were performed by the help of statistician to compare the different technologies by a varying number of factors, namely: The average number of eggs per hen, the average weekly mortality, the average weekly cumulative mortality, the feed conversion ratio, and the average weekly egg production capacity. We found that it is not reasonable to compare the number of hatch eggs and amount of feed consumed because both parameters are related to the number of chickens housed.

CHAPTER 5

Data analysis

5.1 Descriptive Statistics

5.1.1 Egg Production %

What can be seen in both figure 17 and figure 18 is a unified increase in egg production up until peak production as the birds mature and start to produce eggs, following this is a gradual decrease, ending in a sudden drop in egg production as birds are slaughtered. As an overview, all farms follow a similar pattern to this, some more delayed or with higher peaks than others.

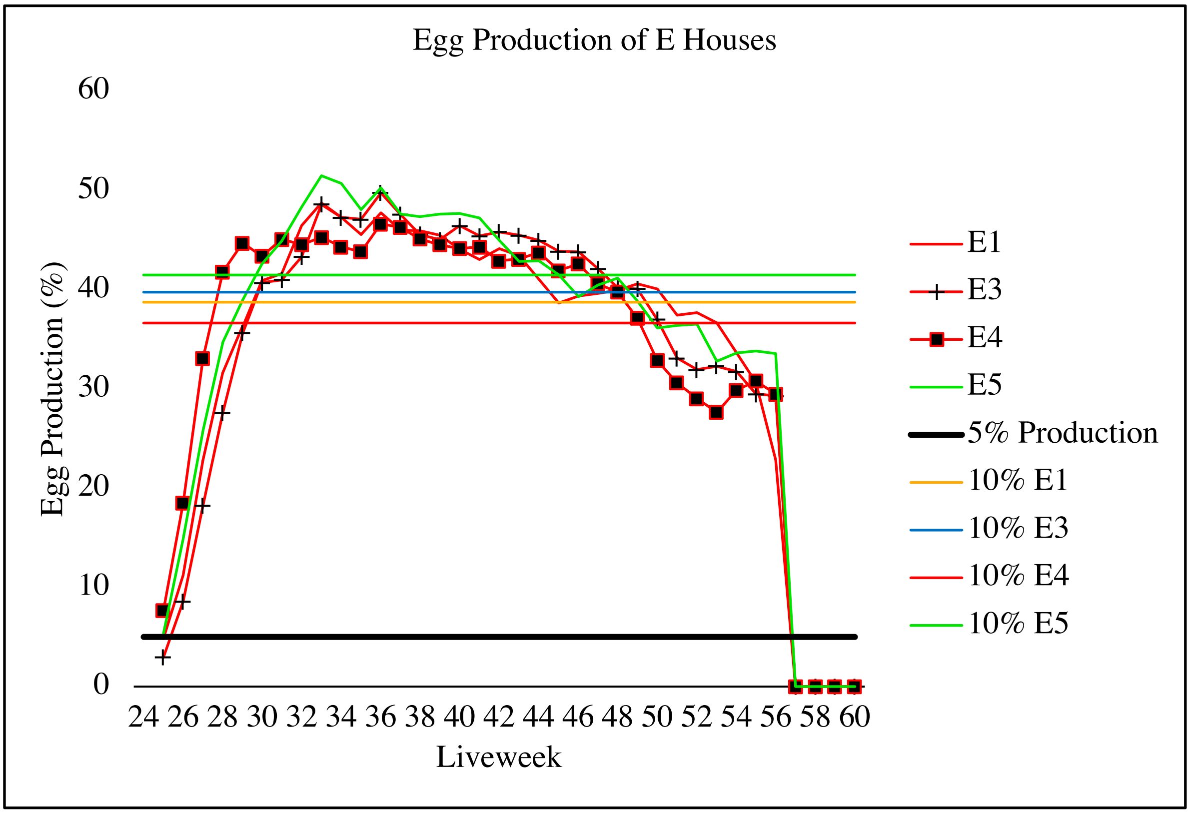

Figure 17 (above) Egg production % of the E Houses different barns using the A and C technologies starting from the week of their production starting.

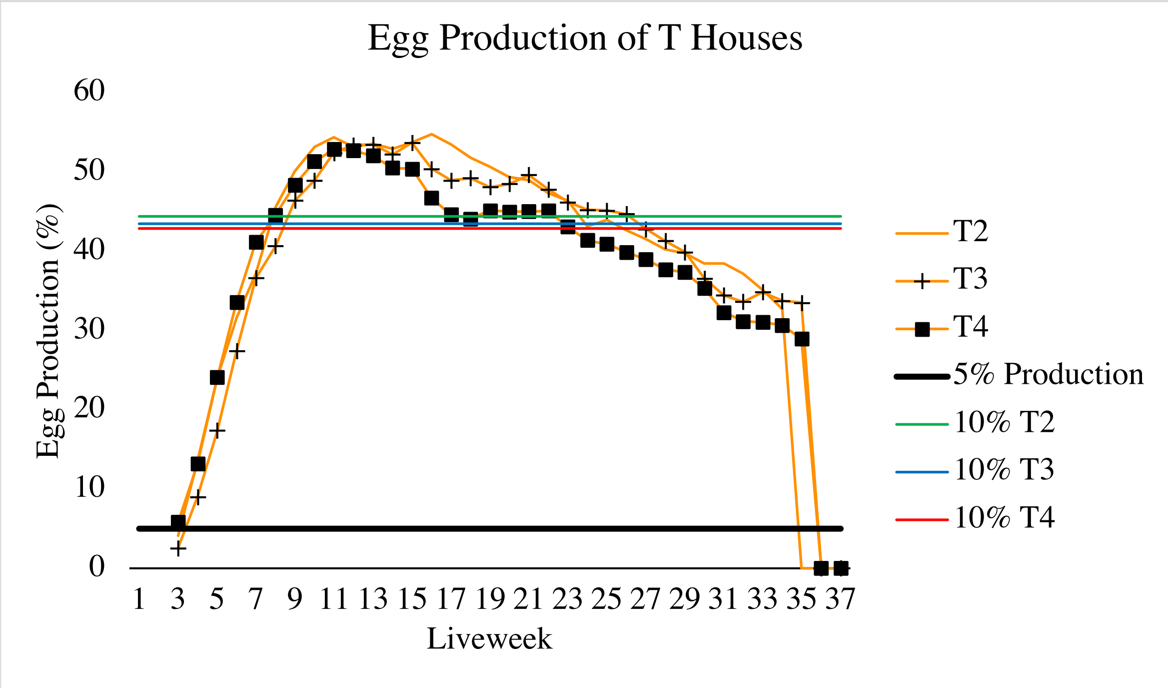

Figure 18 (above) Egg production % of the T Houses different barns using the B technology starting from the week of their production starting.

5.1.2 Age at Peak Production

The age of peak production shows us the age at which the birds are producing the greatest number of eggs. From figure 19, we can see that A and B technologies peak at a similar age, with variability within the technology groups. The C technology has a comparably lower age when the birds are at their highest production.

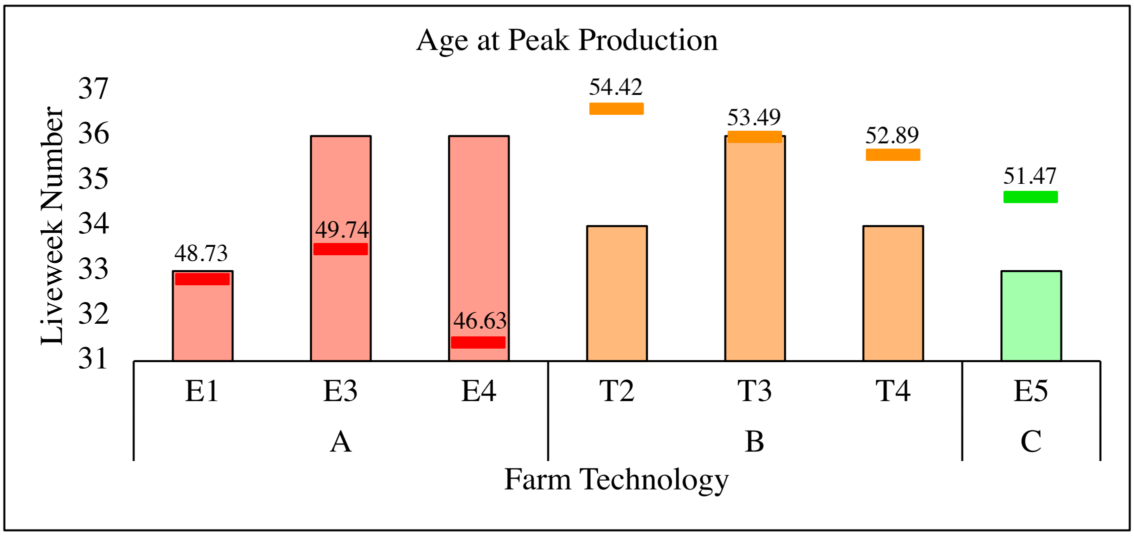

Figure 19 (above) The age at which each the different barns using the A, B and C technologies reach peak production. Each barn's peak productivity % is also indicated on top of each bar.

5.1.3 Persistency

The persistency is the number of days at which the egg production remains above a threshold of 10% of the respective peak production. All technologies show not too dissimilar results, however, what figure 20 shows us is that technology A has a higher persistency amongst the groups, while B and C have a similarly lower persistency.

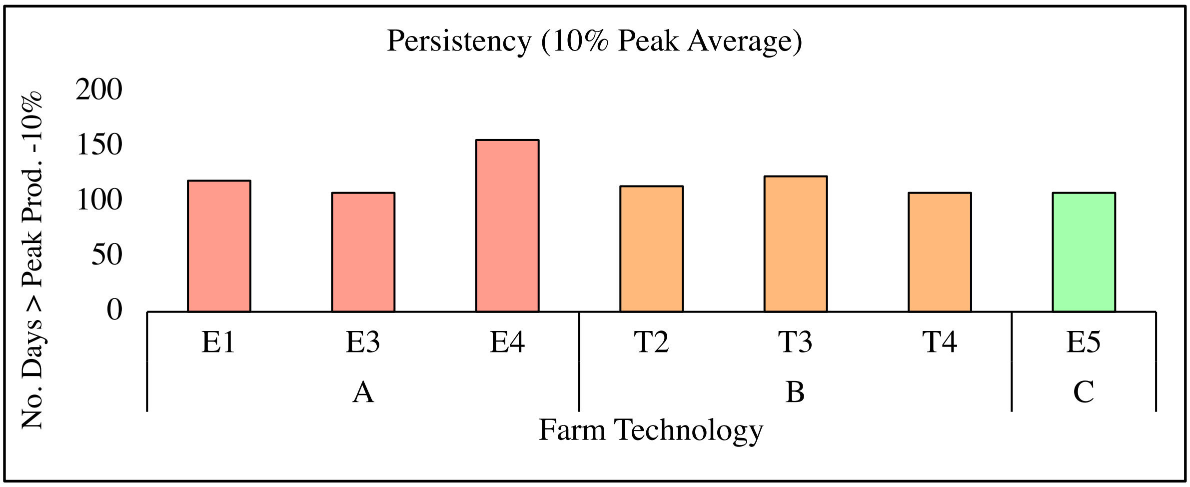

Figure 20 (above) The number of days each of the different barns using the A, B and C technologies maintain production within a threshold of 10% of the peak production.

5.1.4 Total Hatch Eggs

From observing figure 21, A technology has the lowest number of eggs produced, while C technology has the highest number of eggs produced. The B technology holds values between those of A and C technologies.

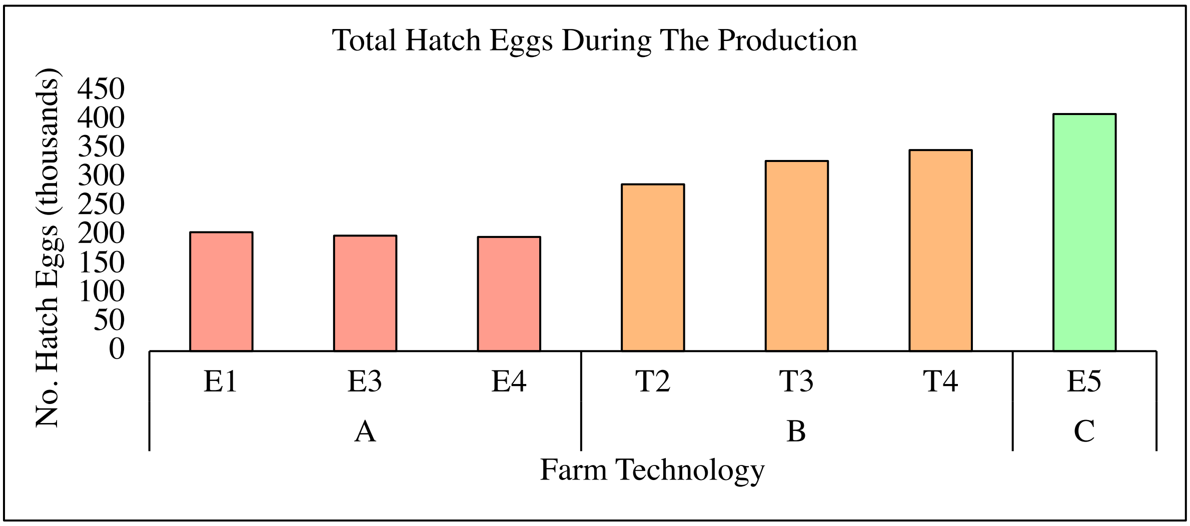

Figure 21 (above) The number of eggs each of the different barns using the A, B and C technologies produced in the measured period, measured in thousands.

5.1.5 Feed Conversion Ratio

From figure 22, technology A has a much lower FCR than that of B and C, and that this finding is similarly found between both hens and cocks. Upon initial observations, the B technology has the highest average FCR. Comparing the cocks, however, the difference between technologies is not as great as that of hens.

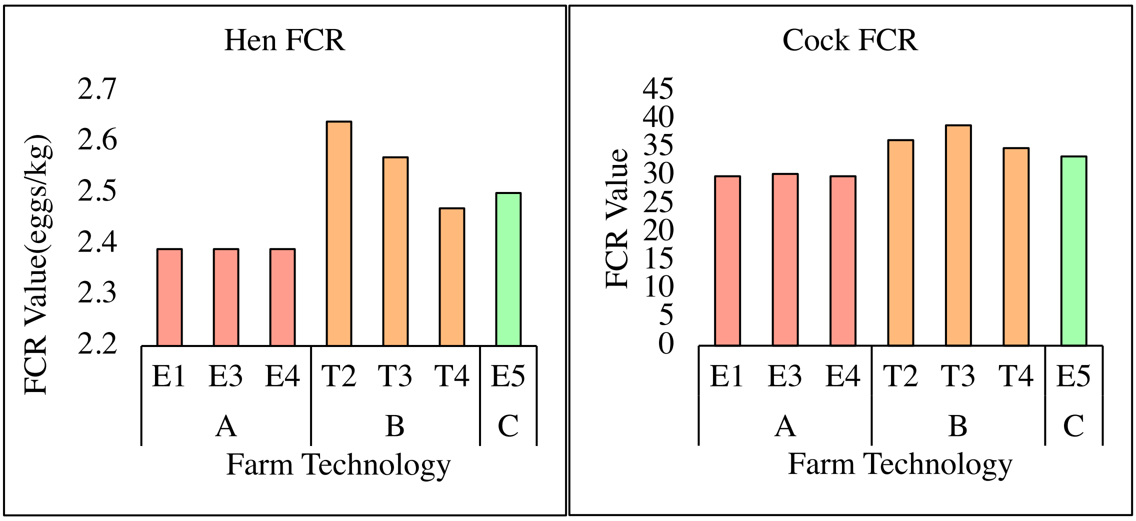

Figure 22 (above) The FCR for the hens (left) and cocks (right) at each of the different barns using the A, B and C technologies.

5.1.6 Cumulative Mortality

From figure 23, we can see that technology A has a much lower cumulative mortality than the other technologies, this is expressed between both the hens and the cocks. The B and C technologies have a similar cumulative mortality to each other, but exceed that of technology A.

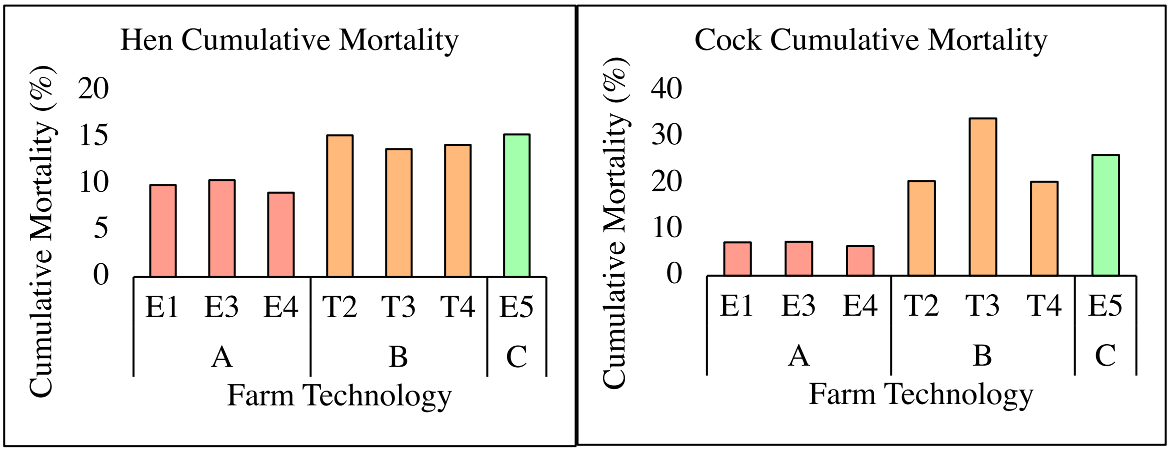

Figure 23 (above) The cumulative mortality for the hens (left) and the cocks (right) at each of the different barns using the A, B and C technologies.

5.1.7 Other Descriptive Statistics

Table 5 (below) The data used to produce the previous figures along with additional data produced using the production table and daily report provided by the farm.

		Farm Technology						
Technology			A			B		C
Farm		E1	E3	E4	T2	T3	T4	E5
5% Production age (wk.)		25	26	25	26	27	26	25
Peak production age (wk.)		33	36	36	34	36	34	33
Slaughter age (wk.)		58	61	61	57	58	59	56
Peak production (%)		48.73	49.74	46.63	54.42	53.49	52.89	51.47
Peak production – 10% (%)		38.73	39.74	36.63	44.42	43.49	42.89	41.47
Egg production persistency		78	108	156	114	123	108	108
Total hatch eggs (10,000s)		20.58	19.98	19.76	28.87	32.91	34.79	41.03
Feed/100 eggs (kg)		41.91	41.91	41.78	37.64	38.47	40.36	39.93
Production days		216	218	218	223	229	238	219
FCR	*Hens*	2.39	2.39	2.39	2.64	2.57	2.47	2.50
	Cocks	29.94	30.35	29.94	36.32	38.94	34.91	33.44
Cum. mortality (%)	*Hens*	9.87	10.39	9.06	15.21	13.74	14.20	15.31
	Cocks	7.20	7.35	6.37	20.45	34.02	20.33	26.12
5% Prod. BW (g)	*Hens*	3569	3893	3850	3405	3589	3612	3641
	Cocks	3275	3672	3556	3855	3759	3641	3683
Peak prod. BW (g)	*Hens*	4167	4205	4190	4047	3998	4165	4128
	Cocks	3836	4272	4052	4107	4375	4131	3946
Slaughter BW (g)	*Hen*	4708*	4224*	4456*	5011*	4289	4466*	4412
	Cocks	4176*	4396*	4655*	5391*	5301*	5063*	4936

* Where this data was unavailable for the specific week, the last previously available data was used instead.

5.2 Comparative Statistics

5.2.1 Number of Hatch Eggs per Hen

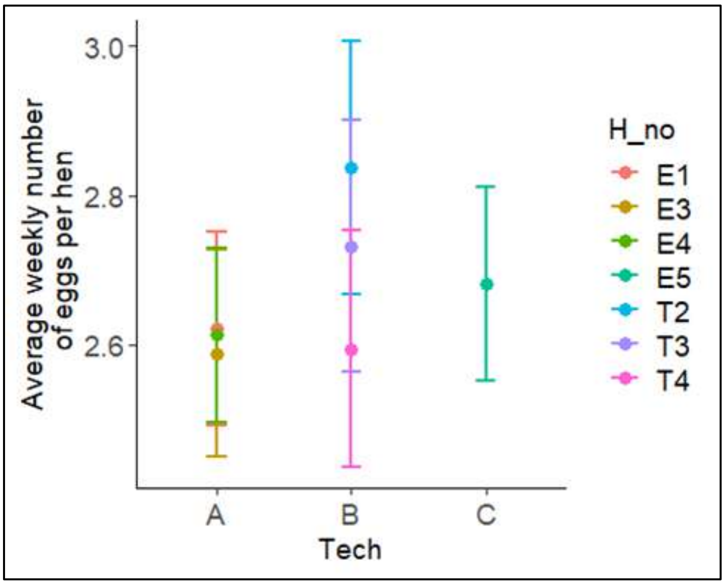

Figure 24 (above) Comparative statistics comparing the average number of eggs per hen with A, B and C technologies.

Figure 24 shows slight variation in the average weekly number of eggs per hen between the different technologies, with the B technology showing the most variability. The number of eggs per hen appears to be greater in C than in A, but it appears difficult to compare the B technology due to the variability.

5.2.2 Average Weekly Mortality

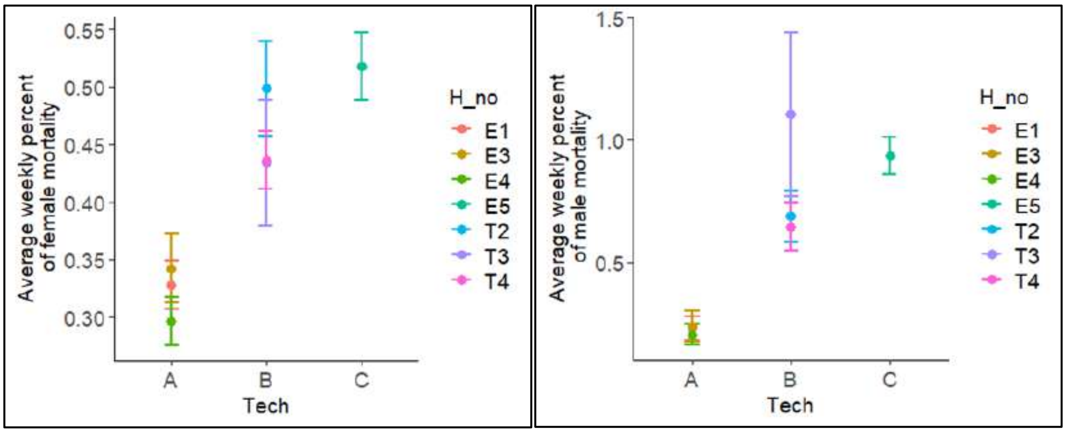

Figure 25 (above) Comparative statistics comparing the average weekly female mortality (left) and average weekly male mortality (right) with A, B and C technologies.

Figure 25 shows that hens appear to have the lowest average weekly mortality in the A technology group, and the highest mortality in the C technology group. The B technology appears to lie between these groups' mortality values and with a high level of variability in the data compared with the other groups. This pattern is repeated in the cock group, with variability particularly seen in the "T3" barn.

5.2.3 Average Weekly Cumulative Mortality

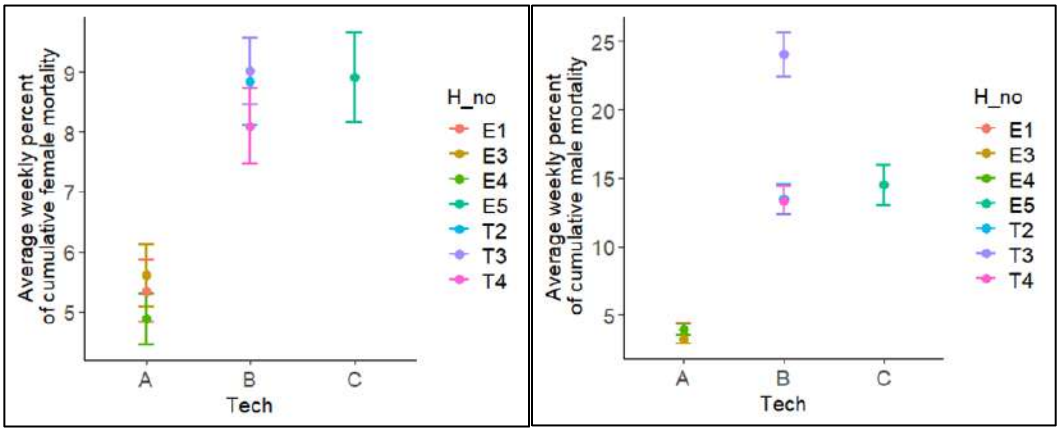

Figure 26 (above) Comparative statistics comparing the average weekly cumulative female mortality (left) and average weekly male mortality (right) with A, B and C technologies.

The average weekly cumulative mortality data expressed in figure 26 follows a similar trend to that of the non-cumulative mortality, with the A technology having the lowest, however, the B and C technologies appear to have similar values in this regard. The "T3" group appears not to match the values of the other lines using the B technology.

5.2.4 Feed Conversion Ratio

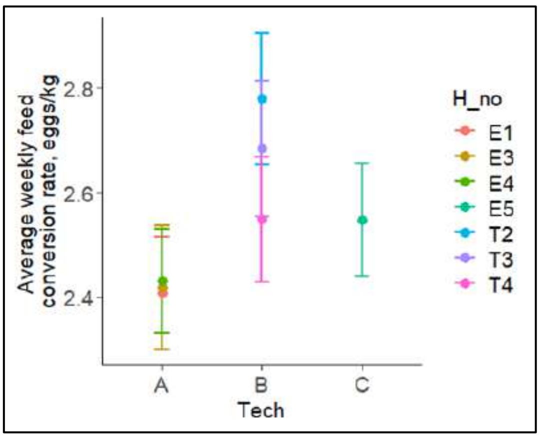

Figure 27 (above) Comparative statistics comparing the average FCR with A, B and C technologies.

The FCR seen in figure 27 appears to show the A technology having the lowest and the B technology, with the most variability, having the highest values. The FCR values of C technology average between the A and B technologies.

5.2.5 Average Weekly Egg Production

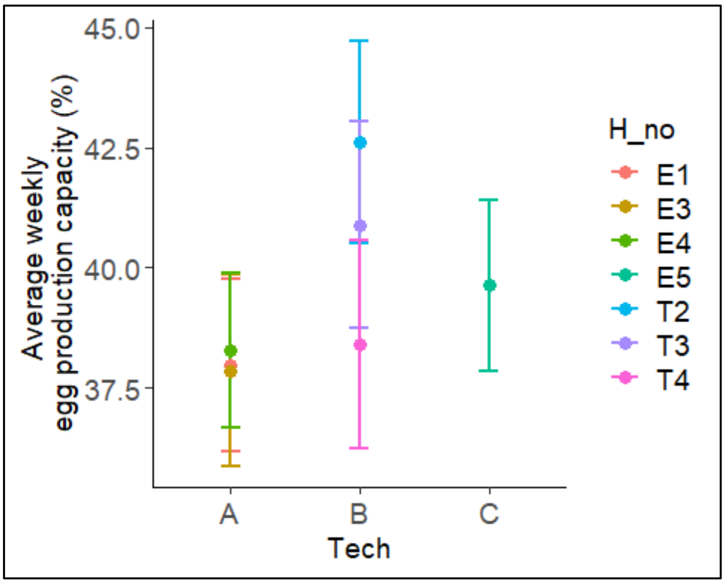

Figure 28 (above) Comparative statistics comparing the average weekly egg production capacity with A, B and C technologies.

The average weekly egg production data summarised in figure 28 shows A technology to have the lowest values and B technology to have the highest with C technology between A and B. There appears to be high variability in the data, with all groups' data overlapping.

5.2.6 Summary of comparative statistics

Table 6 (below) A summary of the conclusions drawn from the comparative statistics

Test	Differences amongst all barns	P-Value
Average no. eggs per hen	Non-significant	0.64
Average weekly mortality	Significant	<0.05
Average weekly cumulative mortality	Significant	<0.05
Feed conversion ratio	Significant	<0.05
Average weekly egg production capacity	Non-significant	0.28

CHAPTER 6

Discussion

With increasing research and development in the agricultural sector, it may be expected that over the last 50 years, the productivity of poultry farming would increase, however, after reading the data analysis, some unexpected conclusions may be drawn. From figure 19, we can see the A and B technologies have birds which reach peak production at a similar age. When we compare this with the C technology, it may be taken that the birds in the C technology reach peak production at a younger age, and therefore reach peak production faster. With this information, we can also compare the persistency data from figure 20 meaning that although C technology reached peak production earlier, the time at high production is sustained for a similar length of time to A and B technologies. From this, it may be found that C technology may have similar productivity to A and B but can reach its peak faster. In the eyes of farmers, this could be seen as more advantageous. Analysing figure 21 at face value shows that the number of eggs produced increase with the more modernised technology. This figure is however misleading, as noted previously that the number of birds housed in technology C are greater than that of B, and B are greater than that of A. Calculating the hatch egg number for 1000 birds/house would potentially aid in comparing these data. What we can deduct from the FCR of the farms (figure 22), is that the oldest technology (A) gives the lowest FCR value in the study, with the most modern technology (C) having only a slightly higher FCR. What is interesting is that the technology from 2015 (B) has the highest feed conversion ratio of the farms, which shows this farm seems to be less productive than the others. This is supported by the comparative statistics (figure 27) to show that these differences are significantly different. . What can be drawn from the cumulative mortality data shown in figure 23 is that the newer technologies (B and C) in this study have been associated with higher mortality rates, and the comparative statistics of the mortality and cumulative mortality shows that these differences in mortality data are significantly different (figure 25 and figure 26 respectively). The significantly lower mortality rates in the A technology would be a supporting factor in the conclusion that A technology is more productive than B and C. Table 5 shows that the number of production days are higher in the B technology farms, which if they are producing eggs for longer periods would make this technology more favourable in the economics of the farm. From analysing the data, it is seen that technology B has the more favourable prospects, statistically, based on the data seen from the feed conversion ratios, and the number of production days.

Unique factors that are found in the B technology, such as the cock feed troughs are likely to be seen as directly favouring the barns, the secondary effects of such technology can have a knock-on effect on the productivity. Assessing the mortality data, we see A technology to be more favourable because even though these have the highest stocking densities, they also have the lowest mortality making them favourable in the economics of the modern farm. What is interesting is that while these technologies seem to be showing promising results, the C technology farm is not showing any significant yields in this study. . The flock performance is multifactorial, so not only the housing technology impact it. We also need to consider that the results seen may also be heavily affected by the genetics of the birds, among many other factors Will we see drastic improvements over the next 3 years in productive values as the barn settles and workers adapt to the new system? Future studies repeated in another production period, with historical data from the same farm would be necessary to get a real picture of C technology. Comparison of these would increase precision and may lower the chance of systematic error. While it may be clearer where the more productive technology lies, this study does not consider the ethical and political factors that the poultry sector is facing today. As we have discovered from this study that the older-style farms in this sector have lower mortality rates than those seen of today's farms, it is very likely that modernisation remains controversial in the wider picture, not only from an animal welfare perspective, but from a productivity aspect too.

CHAPTER 7

Summary

This thesis evaluates the production of grandparent flocks on deep litter with slat in various modernised technologies, and how these technologies have changed in the last 50 years. From a grandparent broiler farm in Hungary, several data were obtained, analysed, and evaluated to help draw a conclusion as to whether the progress and development of farming technology has been becoming more productive over the last half-century. The farming technology groups considered were those built in 1970, 2015 and 2018, and would form the basis of the comparative study. With these groups, a number of productive parameters were compared by numerical data, descriptive statistics, and comparative statistics. The statistical analysis of the data revealed both logical and unexpected findings. The timing of peak production analysed together with the persistency data shows the most recent technology to be more advantageous by farmers. However, when evaluating the FCR and mortality data it would suggest that the technology from 1970 is more advantageous. Parallel to this, we find the technologies from 2015 and 2018 have significantly higher mortality rates than in those barns from 1970. Based on these, it cannot be clearly stated that one technology is better than the other. Effective production is multifactorial, so can be realized in all technologies by coordinating management factors.

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which I deem suitable for submission and defence.

Date: Budapest, 11 day 11 month 2022 year

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