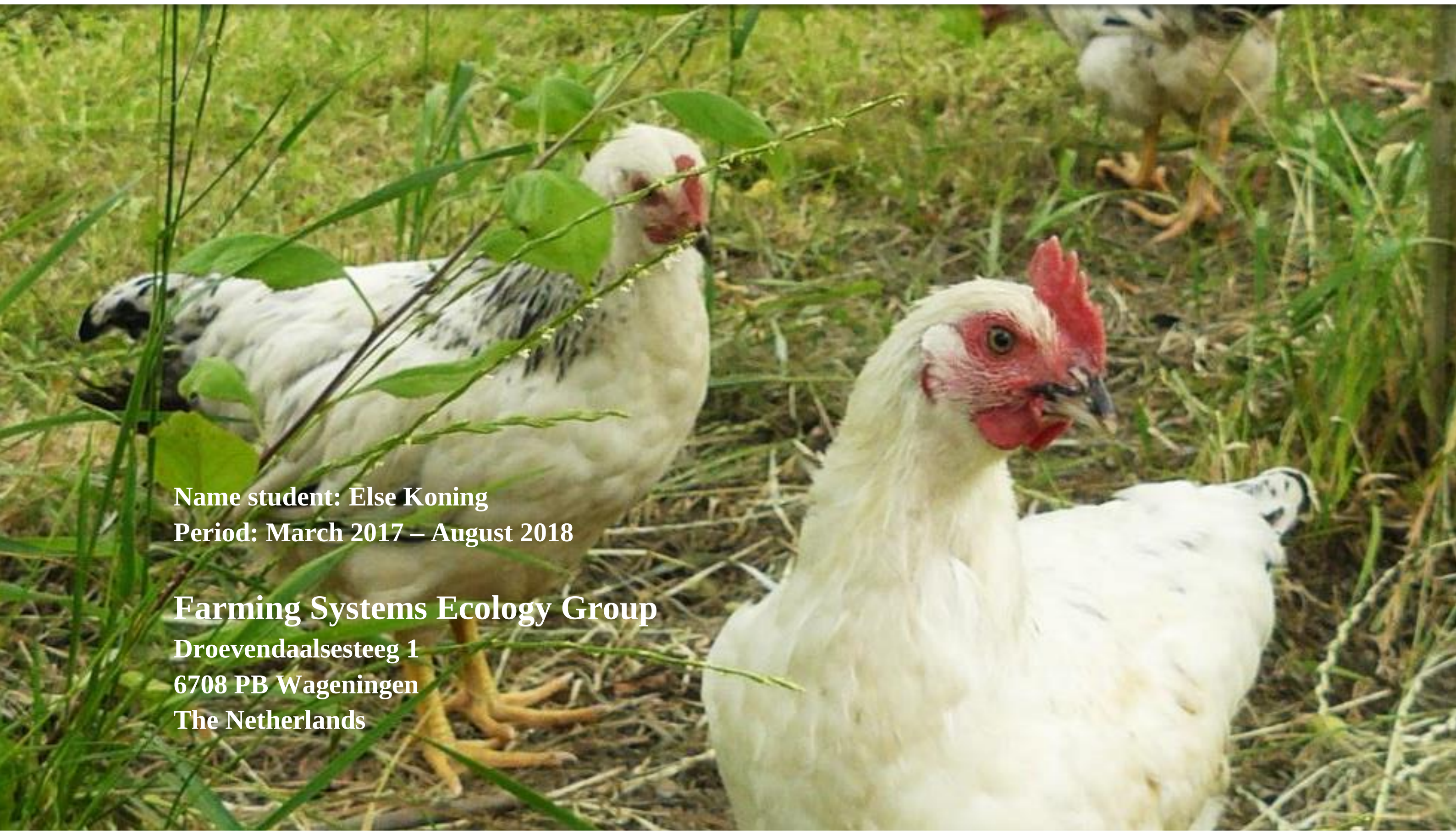
Restoring functional interrelationships between livestock and agricultural crops

Investigating the economic and environmental sustainability of an integrated broiler rearing system in a biodynamic fruit orchard



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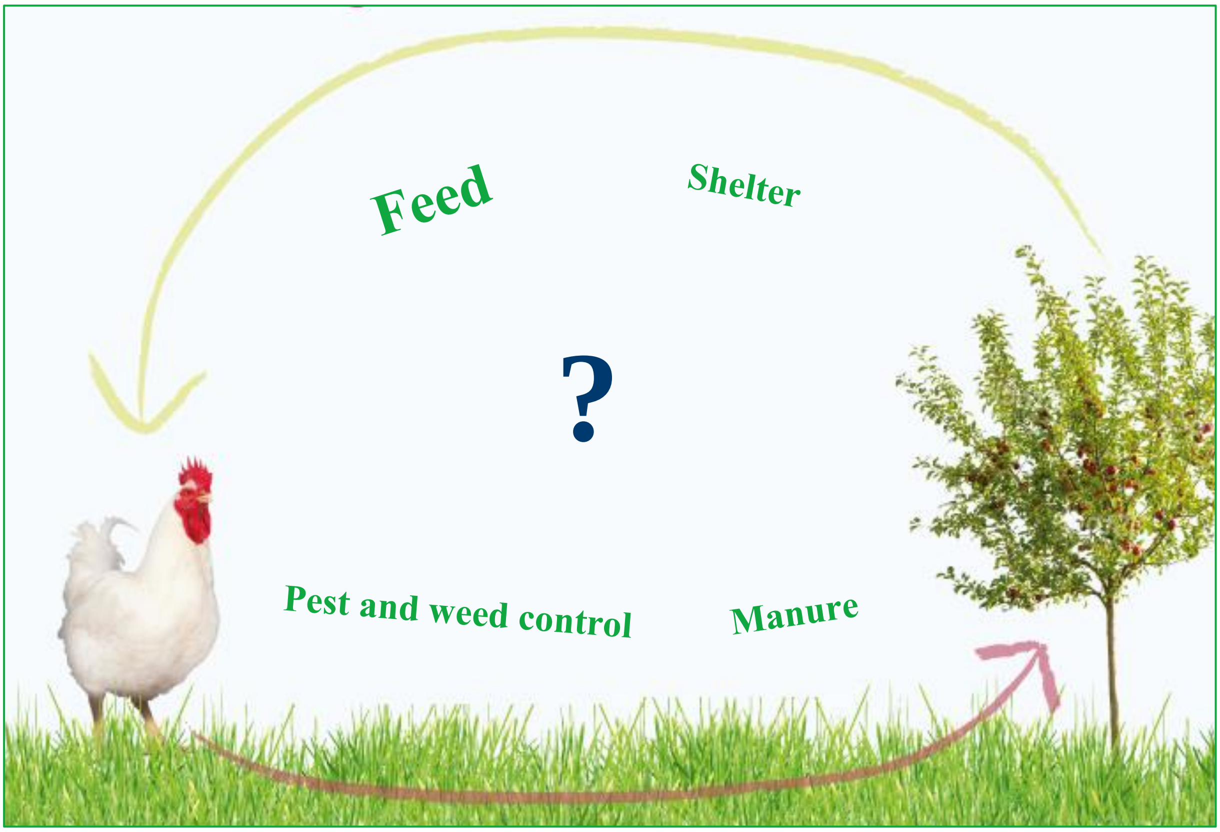

Figure 1: The manifold functional interrelationships at play when Galliformes free range an orchard environment. This study zooms in on the potential contribution of orchard forage (e.g. invertebrates, fruit droppings, understory vegetation) to broiler diets. *(Source: original artwork for Kip van West by Pieter Ploeg, edited by author)*

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Abstract

Over the last century Europe's traditionally biodiverse farming systems were compartmentalized into industrialized monocultures. Although this shift has increased yields, it has also increased resource extraction and pollution. By combining different agricultures so that they are mutually supportive and provide critical ecosystem services, Diversified Farming Systems (DFS) mean to regain ecological functioning and reduce reliance on external inputs and waste disposal.

For this thesis the economic and environmental sustainability of a DFS that rotates Organic (Hubbard JA95) broilers in mobile pens through a biodynamic fruit orchard was investigated. The research project more specifically zoomed in on the potential contribution of orchard forage to broiler diets – the main determining factor to both the environmental and economic cost of broiler production. It was hypothesized that DFS broilers, due to daily access to fresh forage, could achieve standard organic growth rates while subjected to relatively sober dietary treatments. Additionally, the thesis tested whether hypothesized low feed inputs might allow for the viable integration of dual purpose (Vredelinger) cockerels into the DFS and, by extension, compared the economic trade-offs involved in rearing standard organic broilers versus the male offspring of a dual purpose chicken.

An ad libitum diet in which concentrate was substituted by spelt for 50% was trialled on Hubbard JA95 and Vredelinger. Despite the protein poor diet, the Hubbard achieved a Feed Conversion Ratio (FCR) similar to the Dutch organic average (2.43 – 3.40 kg Feed Consumed kg LW^{-1}). The Vredelinger performed significantly worse both in terms of Live Weight and FCR (4.23 – 4.85 kg Feed Consumed kg LW^{-1}, $P<0.05$). Unlike the Hubbard, it did not turn out profitable within the DFS; The profit margin of the first was 19%, while the second netted at a loss of -8%.

In a later rearing cycle Hubbard broilers were subjected to the same dietary formulation on a restricted basis. These broilers achieved similar Live Weights to their predecessors, but at a substantially lower Feed Consumption per kg of weight gain than the Dutch organic average (1.94 – 2.07 kg FC kg LW^{-1}). In fact, their FCR equalled that of faster growing breeds on the Dutch market. The extra environmental impact normally associated with the higher feed requirements of organic broilers was eliminated for this batch, while the profit margin op the operation was upgraded to 21%.

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1. Introduction

1.1 Reviving Diversified Farming Systems

In the aftermath of World War II Europe rapidly replaced its traditionally biodiverse farmsteads for highly industrialized monocultures (Kremen & Miles, 2012), a transition that set off in the Netherlands from the 1960s. The Post-war agricultural policy was squarely fixated on the alleviation of food shortages, with maximum production at minimum cost as its single objective (Napel et al., 2006). In the wake of the industrial revolution the way to achieve this was conceived as a technological conquest of nature and the recently subsided arms race just so happened to have left various types of machinery and chemical agents at humanities' fingertips. Chemical fertilisation, pesticide application and increased mechanisation facilitated the rise of the predominant 'Control Model' of agriculture, which seeks to optimize yields by the compartmentalisation and manipulation of crops and livestock to this day (Napel et al., 2006).

While industrialized monocultures have proven themselves highly effective in terms of yield potential, it is increasingly recognized that they lack the internal resource cycling of natural ecosystems (Kremen & Miles, 2012). Their cultivation is crucially dependent on (1) externally extracted yet inexpensive natural resources (e.g. fossil fuels, fresh water and pesticides) and (2) the absorption capacity of externalized waste sinks (Kirschenman, 2012). These reserves are not only finite, their exploitation is also causing substantial social, economic and environmental damage. The unfortunate side-effects include soil degradation, increased greenhouse gas emissions, biodiversity loss, marine dead zones and human exposure to toxic agrochemicals (Kremen & Miles, 2012).

Kremen et al. (2012) advocate a purposeful reintroduction of functional biodiversity in agroecosystems in order to *'reduce negative environmental externalities and decrease social costs associated with industrialized monocultures, enhance the sustainability and resilience of agriculture, and contribute significantly to global food security and health.'* By combining different agricultures so that they are mutually supportive and provide critical ecosystem services, Diversified Farming Systems (DFS) mean to regain their ecological functioning and reduce reliance on external inputs and waste disposal.

One approach to this challenge is to restore the functional interrelationships between livestock and agricultural crops. This study in particular concerns a DFS design that rears broilers in a fruit orchard. The system under study is hypothesized to improve the environmental and economic sustainability of broiler production, while maintaining the animal welfare standards demanded of certified organic practices.

1.2 Balancing welfare and sustainability demands

As Hermansen et al. (2004) point out, simultaneously honouring economic, environmental and animal welfare demands remains a major challenge for the poultry sector. In organic broiler production, economic and environmental trade-offs particularly occur in relation to two welfare regulations: (1) the requirement to provide daily access to an outdoor area, and (2) the requirement to employ suitable breeds with a maximum growth rate of 40 g/day (Skal, n.d.).

Firstly, to allow for the expression of natural behaviour, organic regulations stipulate that chickens should have access to an outdoor area of at least $4m^2$ per bird (Skal, n.d.). This implies the dual disadvantage of an additional environmental impact, land-use wise, in comparison to conventional rearing systems, as well as associated extra production costs. Furthermore, studies have shown that poultry flocks do not spread homogenously throughout the ranging systems commonly provided, resulting in high vegetation pressure in the vicinity of their usually stationary housing and a considerable risk of N-leaching and ammonia volatilisation (Hermansen et al., 2004; Rivera-Ferre et al., 2006). As such, Hermansen et al. (2004) call for *'outdoor/free range systems (for the sake of the livestock), which are constructed and managed in such a way that the livestock, at the same time, exert a positive influence on other parts of the farming system.'*

Secondly, organic regulations reject the use of conventional breeds, mainly because their unrestrained feeding habits and rapid growth are associated with impaired health (Pryce et al., 2004). Although the comparatively slower growth rate of organic broilers is beneficial to physical welfare, it also implies the drawback of lower feed conversion efficiencies. Thus, the greater feed requirements of organic broiler production constitute another environmental and financial disadvantage in comparison to business as usual – and a particular significant one at that, considering the fact that feed inputs represent both the greater part of running costs as well as up to 96% of the total environmental impact produced in the cradle to gate Life Cycle of free range poultry (Paolotti et al., 2016).

Meanwhile, 20th century poultry breeding has culminated in a related welfare issue which remains unaddressed throughout the entirety of the poultry sector. The rise of the broiler bird has rendered the male descendants of any good layer breed economically obsolete; even the growth rate of slower growing broiler strains is far greater than that of layer breed cockerels. As such, the culling of day-old male chicks born from layer breed hatcheries has become standard practice. Although the moral acceptability of their premature death is a normative question eliciting a plethora of differing viewpoints (Bruijnis et al., 2015), it is arguably incompatible with the organic principle to respect animal integrity (IFOAM, 2014; Vaarst & Alrøe, 2011). From this perspective a reintroduction of dual purpose breeds may be desirable – a move which is inevitably accompanied by further economic and environmental trade-offs, considering dual purpose hens direct a substantial part of their nutritional uptake towards egg laying rather than Live Weight gain (Leenstra, 2013). To expand such initiatives beyond upscale niche markets, their comparatively high feed requirements would have to be met more economically than the import of expensive organic feeds allows for.

In the following it is suggested that the issues outlined above may be addressed by integrating broiler and fruit production into one Diversified Farming System (DFS), thus transforming the role of the broiler from passive ‘receiver’ to active ‘harvester and contributor’ (Hermansen et al., 2004).

1.3 Introducing broilers in orchards

Purposefully integrating organic broiler and fruit production provides avenues of opportunity to address the aforementioned sustainability issues without compromising on welfare standards. Farmers may, in fact, enhance the financial and environmental performance of their operations precisely by respecting and employing the innate characteristics and capabilities of Galliformes.

The potential benefits that poultry can provide orchards are manifold, which may explain why raising chickens under fruit trees was actually rather common in the past. Apart from reducing the orchard’s fertilization requirements, a chicken flock aids in biological weed and pest control (Paolotti et al., 2016). While agricultural ‘problems’ such as weeds, pests and manure tend to accumulate into harmful concentrations in separate animal and crop production, they may regain their utility as valuable natural resources in a purposefully integrated system.

The DFS evaluated in this study rears organic broilers in an existing orchard, thereby providing chickens with living conditions resembling those of their jungle-roaming ancestors, while eliminating the additional on-farm land use certified production normally requires (Paolotti et al., 2016). Furthermore, by allowing the birds to forage on row strip plantings, understory invertebrates and dropping fruit remainders, the financial and environmental costs of externalized feed inputs are expected to be constrained.

In a past thesis study at the DFS site, Zandbergen (2016) demonstrated this was the case for the resident laying hens; the concentrate diet of the Lohman Brown flock was substituted by locally procured spelt grain by 50% without affecting laying percentage. Spelt lacks the protein profile to supply a complete poultry diet, but is more affordable and less environmentally polluting (Nguyen et al., 2010) than concentrate. In all likelihood, the DFS hens were able to compensate for the dietary deficit by feeding on protein-rich invertebrates freely available in the orchard.

This study investigated whether orchard foraging broilers can maintain economical growth rates on a similar grain-substituted ration. This is not straightforward, since the protein requirement of a chicken markedly decreases with maturation (Crawley, 2015); the laying productivity of adult hens may therefore be less sensitive to the protein-content of feed than the growth productivity of developing broilers. Furthermore, foraging capacity is affected by both genetic predisposition and learned experience (Almeida et al., 2012; Bassler, 2005; Spencer, 2013) and again reported to be greater in mature hens than in broiler chicks.

While Zandbergen provided laying hens ad libitum access to the aforementioned 1:1 spelt:concentrate mix, this thesis looks into the feed conversion ratio of broilers under both an ad libitum and a restricted dietary regime. The restricted regime was included for two reasons: (1) to assess the scope to further reduce external feed inputs and (2) to stimulate the broilers to search for food out in the orchard in lieu of relying on an endless supply in their feed troughs. Although one study (ICOPP, 2014) showed that free range broilers fed ad libitum foraged more when fed a low-protein diet, the same broilers nonetheless displayed a slight increase in total feed intake as compared to broilers on a nutrient-balanced diet. This finding confirms the observation that chickens *'increase total feed intake as the limiting nutrient in the feed is reduced, attempting thereby to obtain more of the limiting nutrient, until a dietary concentration is reached where performance is so constrained that feed intake falls.'* (Mbajiorgu et al., 2010). Unlike the broilers fed ad libitum, the broilers on the restricted daily ration had limited opportunity to meet their nutrient demand in this way; their restricted daily allowance forced them to obtain any further nutrition from the orchard instead.

An important element of the rearing system at the study site concerns housing. Broilers were kept in mobile poultry pens and moved to fresh alleyway pasture on a daily basis. Practitioners who work with these 'pastured poultry pens' report that regular movement enhances forage intake (Spencer, 2013). Furthermore, this type of mobile housing is easily built at a cost-effective rate and provides the benefit of spreading broiler manure evenly across the range (Zandbergen, 2016).

1.4 Reinstating dual purpose breeds

As elaborated above, rearing cockerels from dual purpose breeds is inevitably less cost-efficient than rearing meat broilers. Leenstra et al. (2014) modelled a 29% reduction in gross margin of egg production when running a dual purpose rather than a specialized broiler breed under standard organic conditions. However, the expected cost-savings from having chickens partially forage their own diet could improve on a dual purpose breed's cost-efficiency. In Zandbergen's thesis project at the DFS orchard (2016), net income from the yearly raising of 375 dual purpose laying hens and 175 cockerels for eggs and meat, respectively, was calculated to be positive by €12500 (a substantial value, which is nonetheless estimated to be 18% lower than the net income that rearing a separate layer and broiler breed would generate).

While Zandbergen's study demonstrated the potential viability of integrating dual purpose flocks of laying hens and cockerels in fruit orchards, the data underlying the financial comparison included several assumptions which remained to be scientifically verified – most notably the notion that the cockerels, when foraging in the orchard, could subsist on a ration of 50% concentrates and 50% grain without incurring a protein deficiency that would affect their growth performance. My study has put this assumption to the test.

2. Research objectives

2.1 Aim and scope

The aim of this study was to implement and evaluate a Diversified Farming System which rotates small scale broiler flocks around an existing biodynamic orchard. The research tested the following hypothesis: *Integrating organic broiler production into an organic fruit farming system enhances its economic and environmental sustainability by reducing feed input requirements.*

Economic sustainability here was defined by net income and profit margin, since these indicators are crucial to the long term viability of a farming business. Environmental sustainability was determined with the Feed Conversion Ratio as a proxy indicator since LCA analysis of free range poultry systems has shown that up to 96% of their environmental impact can be attributed to feet inputs (Paolotti et al., 2016). The orchard provides a certain amount of freely available protein stored in invertebrates and vegetation (Zandbergen, 2016), implying the potential to reduce the DFS broilers' requirement for protein-rich concentrate. As such, it was investigated whether financially (and environmentally) costly concentrate could be substituted with locally procured spelt by 50% and whether feed provision could be reduced to a restricted daily ration of 45 g concentrate and 35 g of spelt / chick / day without negatively affecting Live Weight and Feed Conversion Ratio.

Additionally, this research tested whether dual purpose cockerels could be viably integrated in the DFS designed for low input feed requirements and compared the economic trade-offs involved in rearing standard organic broilers versus the male offspring of a dual purpose chicken. More specifically, it evaluated the relative performance of the Hubbard JA95 broiler and the 11th generation of the Vredelinger: a dual purpose breed developed by Nauta et al. (2011) in response to the organic market's dependency on the conventional breeding industry.

2.2 Research questions

1. *How do Live Weight and Feed Conversion Ratio of the DFS broilers compare to organic production standards when concentrate is substituted with locally procured spelt by 50% and provided ad libitum?*

2. *How do Live Weight and Feed Conversion Ratio of the DFS broilers compare to organic production standards when concentrate is substituted with locally procured spelt by 50% and provided on a restricted ration?*

3. *Is the DFS' broiler branch economically viable?*

3.1 *What is the net income?*

3.2 *What is the profit margin?*

4. *What is the relative performance of Hubbard JA95 and Vredelinger broilers on Live Weight, Feed Conversion Ratio and economic viability?*

3. Materials and methods

3.1 Study site and rearing system

The study was performed in the orchard of Fruittuin van West, a multifunctional urban farm in the Western periphery of Amsterdam, the Netherlands. The broiler rearing system at the farm is modelled on the pastured poultry system for meat birds as described by Perkins (2016) and adapted to fit the DFS context where needed. Production took off from February 2017 and was monitored from the 1st of March that year.

The farmers behind 'Kip van West' aim to raise local meat that surpasses organic standards in terms of quality, environmental sustainability and animal welfare. In light of the latter objective, they have chosen not to raise the fast-growing 'Cornish Cross' type broiler that is usually elected by pastured poultry businesses. Instead they rear a medium grower commonly opted for by Dutch organic poultry farmers: the Hubbard JA95. During the onset of broiler production they also trialled a few batches of Vredelinger cockerels at the farm: the 11th generation of a dual purpose breeding programme set forth by Nauta et al. (2011) in response to the organic market's dependency on the conventional breeding industry.

Figure 2: The two different breeds roaming the orchard when this study was conducted. The Hubbard JA95 (left) is an established slow growing broiler common to organic husbandry. The Vredelinger (right) is the 11th generation of a breeding programme (Nauta et al., 2011) aiming to reinstate dual purpose chickens in the organic industry.

` When day-old chicks arrive at the Fruittuin, they are first brought to an indoor facility, where they remain until they are 3 weeks of age. Dietary treatment does not differ during the stable period, since at this point the chicks do not yet have access to the foraging opportunities that may cut down on their need for supplied feed. In order to fully meet the dietary requirements of young chicks, they are given an undiluted daily ration of concentrate. The facility is heated by heating lamps, a 10 cm layer of spelt chaff bedding is provided and food and water are available ad libitum.

After 3 weeks, the broilers are transferred to the orchard in groups op 50 individuals. Each of these groups is housed in a mobile chicken pen of 8 m^2, compliant with SKAL regulations (Skal, n.d.), and fitted with two food troughs (one for spelt and one for concentrate) and two water troughs. One half of the pen is covered by tarpaulin to provide shelter from the elements, while the other half is enclosed by chicken wire so that the broilers have access to fresh air and sunlight. Importantly, the pens are designed for practical mobility, lightweight enough to be efficiently moved a pen length ahead throughout the orchard's alleyway on a daily basis.

Figure 3: The low cost and light weight mobile chicken pens designed to move the Kip van West chicks through the orchard after 3 weeks of age. Each is 8 m^2 and houses about 50 individuals.

From 6 weeks of age, when the chickens are deemed less vulnerable to lurking predators, the farmer folds away a bit of the pen side's tarpaulin every sunrise so that they are free to roam the orchard. At dusk the majority of the broilers instinctively look for shelter in their pens again. The farmer only needs to herd one or two bold individuals back in, then close the ‘fold away door’ to keep the broilers safe at night.

Figure 4: From 6 weeks of age, when the chickens are deemed less vulnerable to lurking predators, the farmer folds away a bit of the pen side’s tarpaulin every sunrise so that they are free to roam the orchard.

Every day throughout the range period, the broilers and their mobile coops are moved one pen length ahead. This way they continuously retain access to fresh pasture and their manure is gradually spread throughout the orchard. After this daily move they are provided with fresh water and feed (according to the differing dietary treatments described below).


Figure 5: The Kip van West chicken pens are designed for practical mobility, so that they can quickly be moved a pen’s length ahead through the orchard alleyways on a daily basis.

Once the chickens reach around 2 kg live weight they are slaughtered at a small facility in Utrecht, after which the meat is sold in the Fruittuin's on-farm supermarket. Depending on growth rate (which varies with weather conditions and, of course, dietary treatment), a complete rearing cycle should take from 12-14 weeks for the Hubbard JA95 breed and 16-18 weeks for the Vredelinger.

3.2 Treatments

Two different treatments were applied during this study, pertaining to two subsequent rearing cycles in spring, respectively summer 2017. An ad libitum diet of 50% spelt and 50% concentrate was trialled in the third rearing cycle (batch A; starting from April 6), while a restricted diet of the same ratio was trialled in the fifth rearing cycle (batch B; starting from June 1). Since the farmers discontinued the husbandry of Vredelinger chicks before the onset of June, the second treatment could only be applied to Hubbard JA95 broilers.

In other words, batch A included a sample of both Hubbard and Vredelinger chicks, while batch B was limited to a sample of Hubbards. A facility was designed to house the baby birds in separate sections indoors throughout the first 3 weeks of their lives, when they are most vulnerable to predators and the elements. The day-old chicks were allocated by breed, so that the daily feed consumption of the different groups could be adequately monitored. As mentioned above, dietary treatment did not yet differ during the stable period: all chicks were provided ECO Vleeskuikenmeel 1 by van Gorp (see appendix 5 for nutritional details) at an ad libitum basis. However, due to operational hiccups during the first few rearing cycles at the farm, batch A remained indoors 3 weeks longer than batch B; for 6 instead of 3 weeks. (Slaughter of a previous batch was delayed due to overdue paperwork required by the slaughter house, leaving the pens allocated to Batch A occupied for an extended period of time.) Further details per rearing cycle are provided in the paragraphs below.

3.2.1 Batch A – ad libitum diet

Batch A was set up on March 30 and included a sample of 150 Hubbard JA95 and 200 Vredelinger chicks. Mortality during the (6 week) indoor period was 0% for the first and 5% for the second breed. Additionally, once the sex of the Vredelinger chicks could be determined, the hens of the dual purpose breed were collected by the breeder to be included in the Vredelinger breeding program. As such, after

6 weeks, 150 Hubbard broilers and 91Vredelinger cockerels remained.

Before transfer to the orchard, each experimental unit was divided up in groups of about 50 individuals (45 / 46 in case of the Vredelingers). Subsequently, each of these groups was housed in a mobile chicken pen of 8 m^2, compliant with SKAL regulations (Skal, n.d.). Thus, the outdoor experimental set-up consisted of 3 Hubbard JA59 and 2 Vredelinger pens. The multiple groups per breed could unfortunately not be utilized as repetitions, since chicks were allowed to leave their pens after 6 weeks and tended to feed and sleep in pens other than their own. Contamination of data between breeds was successfully avoided by placing the Hubbard and Vredelinger pens at opposite ends of the orchard, leaving their respective feed supply out of each other's reach.

Once outside, the broilers were subjected to an ad libitum diet of 50% concentrate (Van Gorp ECO vleeskuikenmeel 2 from this point onwards – see appendix 6 for nutritional details) and 50% spelt grain. In interest of practicality this 1:1 ratio was provided in terms of volume rather than weight, using measure marked buckets. Concentrate and spelt grain were refilled daily in separate troughs, so that the effective consumption of both could be monitored. Whenever both troughs were found empty by the next feeding round, the daily ration was adjusted up 1 L/pen, so that feed provision nearly always met demand throughout the broilers' development.

Both the Hubbard and the Vredelinger broilers were slaughtered in three rounds, which partially overlapped; the Hubbards were taken to slaughter at 98, 104 and 111 days of age and the Vredelingers at 104, 111 and 139 days of age. For each slaughter round the heaviest chickens – with a target weight of at least 2 kg – were selected from the batch. Mortality during the outdoor period was 1,3% for the Hubbard and 2,2% for the Vredelinger, which means mortality for the full rearing cycle came down to 1,3%, respectively 7,2%.

3.2.1 Batch B – restricted diet

Batch B was set up on June 1 and consisted of 150 Hubbard JA95 chicks. The broilers remained indoors for 3 weeks and mortality during this period was about 2,7%.

Before transfer to the orchard, the 146 remaining chicks were divided up in three groups of about 50 individuals. Again, each of these groups was housed in a mobile chicken pen of 8 m^2, compliant with SKAL regulations (Skal, n.d.). Thus, the outdoor experimental set-up for batch B consisted of 3 coops, housing 49, 49 and 48 Hubbard JA59 chicks, respectively.

At first, the broilers were allowed an adjustment period in which they, like the chicks of batch A, received an ad libitum diet of concentrate (Van Gorp ECO vleeskuikenmeel 2 – see appendix 6 for nutritional details) and spelt grain, again provided in a 1:1 ratio in terms of volume. However, while the daily ration of batch A broilers was adjusted up to meet demand throughout their development, the ration of batch B broilers was limited to a maximum of 6 L/pen/day (3L concentrate and 3L spelt; about 45 g concentrate and 3 g of spelt per chick). This was their fixed daily allowance from day 58 onwards.

All batch B broilers were slaughtered in one go at 90 days of age. Mortality during the outdoor period was 7,3%, amounting to a 10% mortality rate throughout the rearing cycle.

3.3 Measurements and analysis

In order to answer the first two research questions, feed consumption (FC) and average Live Weight (LW) of the chicks in the respective batches were monitored and compared. Effective intake of both concentrate and grain was measured on a daily basis by weighing the feed supplied and the feed which remained in the feeding trough the following day. Since feeding troughs were shared among chicks, the average FC per broiler was calculated from the total FC recorded divided by the amount of chicks sharing the troughs at each point in time. The average LW of the chicks was assessed from the point when the chickens were about 81 days of age (the minimum slaughter age compliant with SKAL regulations) onwards. Subsequent measurements were performed in order to monitor the development of the feed conversion ratio (FCR) over time and aid the farmers in deciding on the optimum slaughter age for future batches. 10 broilers per breed were randomly sampled during each measurement – a practical and sufficient sample size in order to test the statistical significance of an assumed minimal weight difference of 0.25 kg (two-tailed α: 0.05; 1-β: 0.80; assumed SD: 0.20 kg). In case of the Hubbard two gender-selective b

ut otherwise random samples were taken for each measurement and the resulting data sets for hens and cockerels were averaged (since cockerels are generally heavier than hens, an imbalanced selection in terms of gender would have delivered skewed data). Data were first examined for normal distribution using the Shapiro-Wilk normality test. Group data were compared using t-tests in case of normally distributed data, while Mann-Whitney tests were applied when data were skewed.

With respect to the third research question, the actual returns and production costs of the respective rearing systems (varying by breed and feeding scheme) were monitored. Returns were measured in terms of meat sales and production costs in terms of costs for day-old chicks, feed, energy, water, labour, and depreciation of housing pens. Additionally, costs of slaughter and labour and materials involved in direct sales were accounted for. From these data the net income derived from the respective rearing systems and their associated profit margins were calculated.

Finally, the slaughter weights, FCR, net income and profit margin of the respective experimental units were compared both to each other as well as to standard values characterizing broiler rearing systems common to organic farms as derived from literature.

4. Results

4.1 Growth rate and Food Conversion Ratio: Batch A - ad libitum diet

Batch A included both breeds and was subjected to an ad libitum diet consisting of 50% concentrate and 50% spelt. Table 1 lists the broiler's average Live Weight (LW) as recorded at 76, 104 and 110 days of age. The average LW of Vredelinger broilers was consistently lower than that of Hubbards throughout the rearing period ($P<0.05$). While the Hubbard approached the marketable slaughter weight desired by the farmers (2 kg) somewhere in-between day 76 and day 104, the Vredelinger did not reach this level of weight at all even after 110 days.

Table 1: Average Live Weight (LW) and Feed Conversion Ratio (FCR) of Batch A broilers over time

Age (days)	LW Hubbard (kg)	FCR Hubbard (kg FC / kg LW)	LW Vredelinger (kg)	FCR Vredelinger (kg FC / kg LW)
76	1.79 ± 0.13 *	2.43 ± 0.19 *	0.79 ± 0.12 *	4.85 (4.35-5.50) *
104	2.31 ± 0.41 *	3.40 ± 0.86 *	1.35 (1.13- 1.45) *	4.23 ± 0.58 *
110	2.65 ± 0.32 *	2.93 ± 0.36 *	1.29 ± 0.16 *	4.60 ± 0.55 *

Normally distributed data presented as mean ± standard deviation. Skewed data presented as median (interquartile range).
*All comparisons were statistically significant at ($P<0.05$)

In Figure 6 the growth of the broilers is shown alongside their average Feed Consumption (FC) over time. As can be observed below, the Vredelinger broilers did not only gain less weight but also, on average, consumed less feed than the Hubbards.

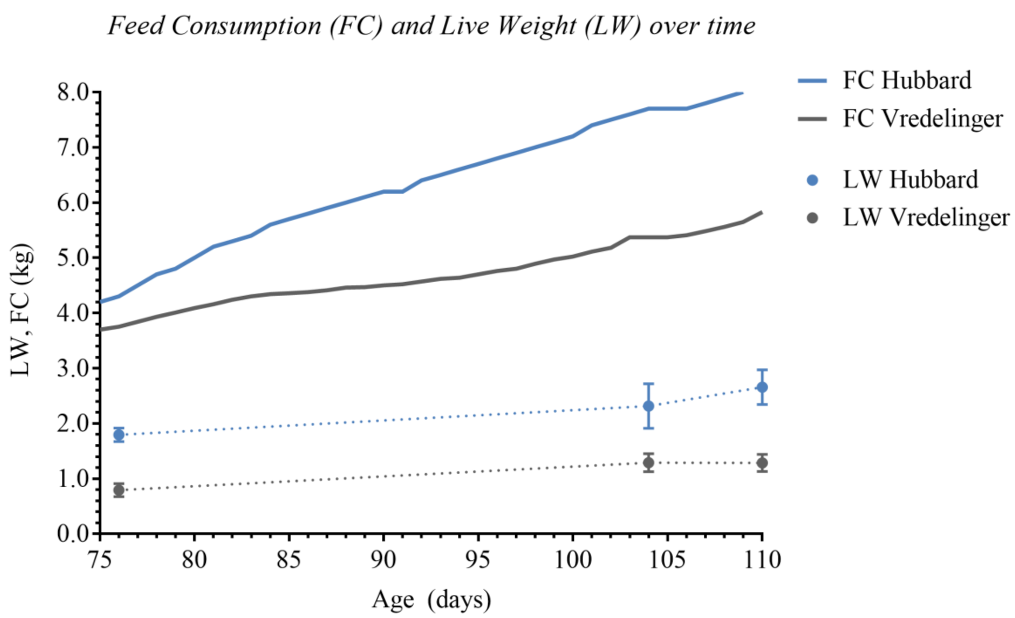

Figure 6: Average Feed Consumption (continuous line) as measured from day 75 – 110 and average Live Weight

(dots) as measured on day 76, 104 and 110, per broiler breed raised in the third rearing cycle. Batch A Hubbards (blue) and Vredelingers (grey) were both subjected to an ad libitum 1:1 spelt:concentrate diet.

By dividing the abovementioned values (average FC by average LW), the average Feed Conversion Ratio's (FCR) at 76, 104 and 110 days of age were assessed (see Table 1). At any of these data points the FCR of the Vredelinger breed was significantly higher than that of the Hubbard ($P<0.05$). Thus, although the Vredelinger's Feed Consumption was relatively modest, its weight gain per kg FC was still significantly less efficient as compared to that of the Hubbard.

In Figure 7 the development of both breeds' FCR is plotted. The green line indicates the average FCR for organic chicken in the Netherlands (2.63 after Ellen et al., 2012). The Hubbards' FCR (blue line) approximated this value at 76 days of age, implying that the weight gain of the broilers was not impaired by their relatively protein poor diet. Nonetheless, the Hubbards' FCR at 104 days of age exceeded the Dutch Organic average by 0.77 points, underlining the importance of timely slaughter when it comes to efficient feed utilization. Meanwhile, the FCR of the Vredelinger breed (grey line) far exceeded the Dutch Organic average at any point throughout the rearing period.

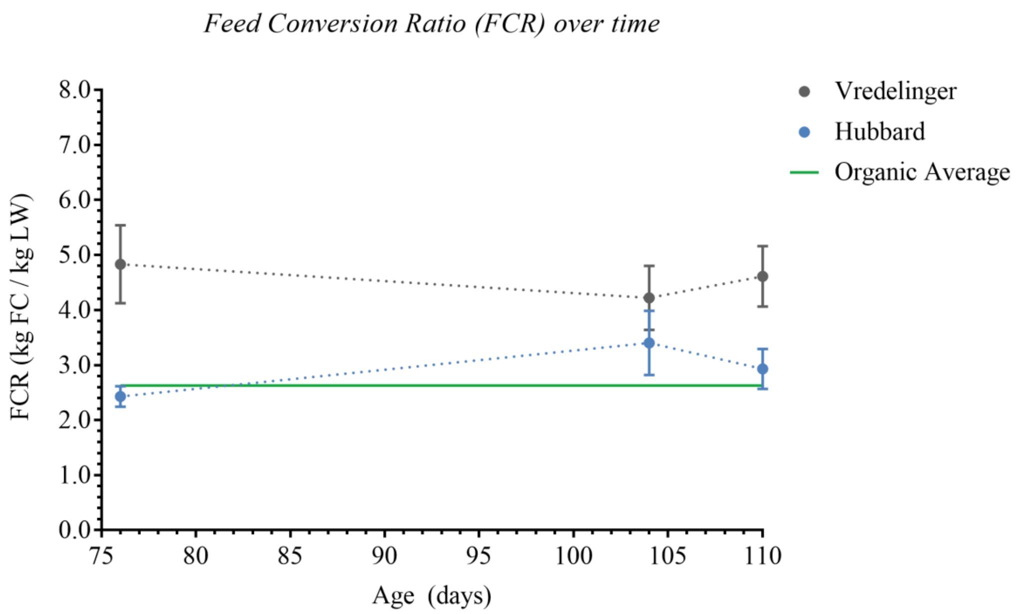

Figure 7: Average Feed Conversion Ratio of Batch A broilers subjected to a 1:1 spelt:concentrate diet, as calculated at 76, 104 and 110 days of age. The Dutch Organic average FCR (Ellen et al., 2012 – continuous green line) is shown alongside the Vredelinger (grey dots) and Hubbard (blue dots) FCR as a benchmark value.

4.2 Growth rate and Feed Conversion Ratio: Batch B - restricted diet

Batch B only included Hubbard broilers. These chicks were again subjected to a diet consisting of 50% concentrate and 50% spelt grain, but from 58 days of age onwards their feed was administered on a restricted basis (6 L/pen/day, 50% concentrate, 50% spelt). The average Live Weight (LW) of the broilers was assessed at day 78 and day 90 and measured 1.78 (SD = 0.15) and 2.38 (SD = 0.22) kg, respectively (table 2).

Table 2: Average Live Weight (LW) and Feed Conversion Ratio (FCR) of Batch B broilers over time

Age	Live Weight Hubbard (kg)	FCR Hubbard (kg FC / kg LW)
78	1.78 ± 0.15 *	2.07 ± 0.18 *
90	2.38 ± 0.22 *	1.94 ± 0.18 *

Normally distributed data presented as mean ± standard deviation.
* All comparisons were statistically significant at (P<0.05)

In Figure 8 these values are shown alongside average Feed Consumption (FC). The LW and FC of the batch A Hubbards, already reported above, are again included here for comparison. Interestingly, Batch B developed slightly faster than batch A in terms of average LW, while consuming considerably less feed.

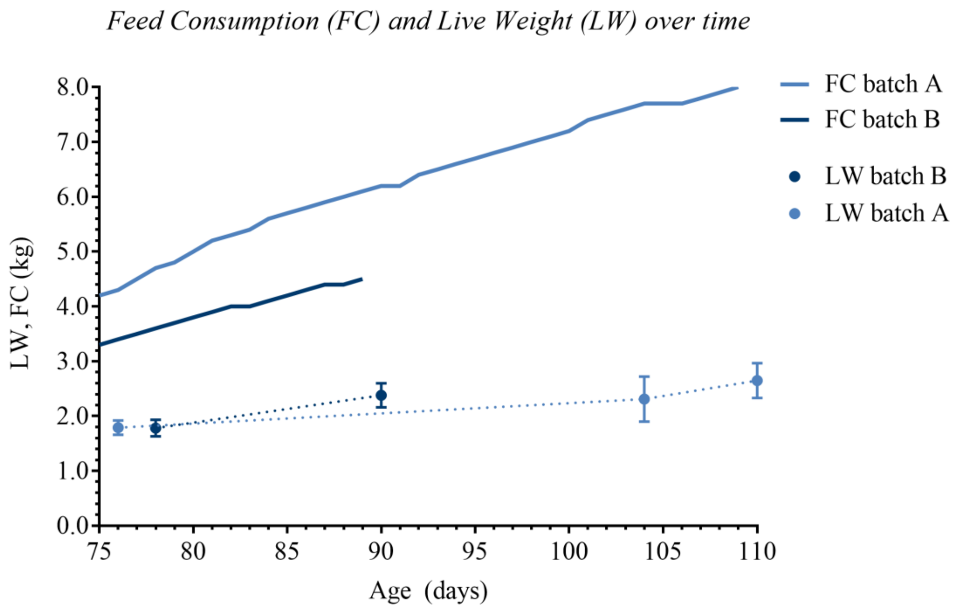

Figure 8: Average Feed Consumption (continuous line) as measured from day 75 – 110 and average Live Weight (dots) as measured on day 78 and 90 of the Batch B rearing cycle (dark blue), in which Hubbard broilers were subjected to a restricted dietary treatment (max. 3:3 L spelt:concentrate/pen/day). FC and LW as measured for the Batch A Hubbard broilers (light blue - see §4.1), subjected to an ad libitum 1:1 spelt:concentrate diet, are included for comparison.

From the above we can already deduce that the Feed Conversion Ratio of Batch B must have been lower than that of batch A. The average FCR of Batch B at day 78 and day 90 came down to 2.07 (SD = 0.18) and 1.94 (SD = 0.18), respectively (see Table 2).

In Figure 9 the FCR values for Batch B are plotted alongside the FCR values for batch A, visualizing the considerable difference in feed utilization efficiency between the different batches. The green line, as before, indicates the average FCR for organic chicken in the Netherlands (2,63 after Ellen et al., 2012). As can be gathered from this figure, the average Batch B broiler (slaughtered at 90 days of age) required about 0,69 kg less feed for each kg of weight gain than the average Dutch organic broiler (Ellen et al., 2012) does.

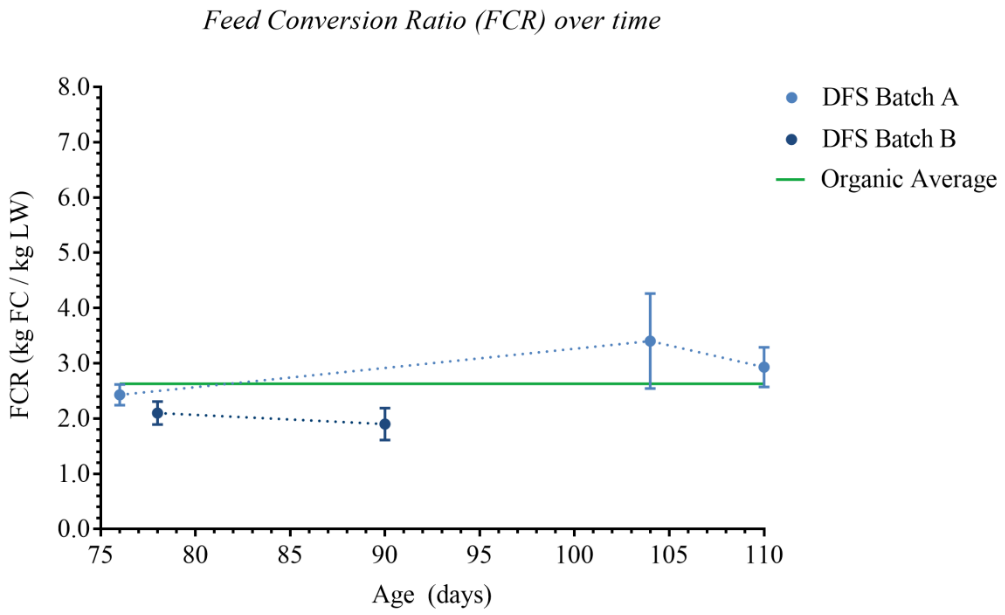

Figure 9: Average Feed Conversion Ratio of Batch B broilers subjected to a restricted diet (max. 3:3 L spelt:concentrate/pen/day) as calculated at 78 and 90 days of age (dark blue dots). FCR as values calculated for the Batch A Hubbard broilers (light blue dots – see §4.1), subjected to an ad libitum 1:1 spelt:concentrate diet, are included for comparison. Additionally, the Dutch Organic average FCR (Ellen et al., 2012 – continuous green line) is provided as a comparative benchmark.

4.3 Cost-return analysis

Table 5: Cost-return structure per batch and breed (n = 150)

1 batch = 150 broilers		Batch A			Batch B
		Hubbard	**Vredelinger**		**Hubbard**
Revenue / batch					
Meat sold (kg)		266,16	141,44		241,23
Sales price (€/kg)		9,95	11,95		9,95
Revenue (€)		2648,28	1690,2		2400,22
30% margin store (€)		794,48	507,05		720,07
Farmer revenue (€)		1853,79	1183,11		1680,15
Production costs / batch					
Feed (€)		458,54	317,01		258,34
Broiler chicks (€)		75,00	100,50		75,00
Labour at €15/hour (€)		528,00	615,50		556,50
Depreciation housing (€)		27,50	27,50		27,50
Water (€)		2,00	2,00		2,00
Electra (€)		7,00	7,00		7,00
Chaff (€)		5,00	5,00		5,00
Total (€)		1103,04	1074,51		931,34
Processing and sales costs / batch					
Slaughter (€)		140,60	129,2		128,25
Transport (€)		52,50	52,50		52,50
Packaging materials (€)		28,12	25,84		25,65
Packaging labour (€)		30,00	30,00		30,00
Total (€)		251,22	237,54		236,4
Profitability / batch					
Net income (€)		**499,53**	**-128,94**		**512,41**
Profit margin		**19%**	**-8%**		**21%**

Table 5 (above) compares the revenue and production costs and resulting net income and profit margin of batch A (Hubbard vs. Vredelinger) and Batch B. Note that the Hubbard calculations are based on the actual experimental set-up of 150 broilers per batch. For the financial analysis of the Vredelinger however, the costs and returns of the actual sample of about 100 cockerels were transposed to reflect a batch of 150 broilers (accounting for the observed mortality rate of 9.2%). This allows for a more accurate comparison of the respective cost-return structure per breed. While both batches of Hubbards provided a positive net income (€499.53 and €512.41, respectively), the Vredelinger, at an estimated net negative of €128.93, did not.

The table sheds light on the main bottleneck to Vredelinger profitability: its relatively low final weight leads to considerably lower revenue, while the sum of its major production costs (feed and labour) hardly differs from that of its Hubbard counterpart. The moderate appetite of the Vredelinger cockerels may have saved €141.53 in feed costs in comparison to the 'hungry' Hubbard, but these savings hardly compensate for a €719.01 loss in revenue. Moreover, an additional €113.00 of costs incurred due to pricier chicks and the extra labour involved in an elongated rearing period, nearly cancels out feed cost savings.

Furthermore, while batch A and Batch B delivered a nearly identical net income, the profit margin of the latter turned out slightly higher than that of the first, despite its greater mortality rate (10% versus 1,3%, respectively). As may be expected from the FCR results reported in §3.2, the improvement in cost efficiency can be attributed to feed savings thanks to the implementation of a restricted feed supply in the 5th rearing cycle; it required about €200 worth of feed less to rear the Hubbards of Batch B to a similar weight level as those of batch A.

5. Discussion

5.1 Growth rate and Feed Conversion Ratio: Batch A - ad libitum diet

This study found that orchard-roaming broilers fed a protein-deficient diet can achieve a FCR similar to the standard for Dutch organic poultry (provided they are slaughtered in time). It should be noted that the benchmark FCR value of 2.63 (Ellen et al., 2012) concerns an estimation of the national average in 2008. Although a more recent value is not available, it seems unlikely that this average has been improved upon in the meantime, since the inclusion of synthetic methionine (an important amino acid for avian physiology in limited plant-based supply) was banned from organic feed in 2012 (Chalova et al., 2015). This assumption is verified by recent literature on organic broiler trials, reporting FCR's of about 2.93 (Cobanoglu et al., 2014; Rezaei et al. 2017). As such, it appears that the ad libitum fed DFS Hubbard indeed achieved an equally (or perhaps more) efficient FCR as compared to current organic standards.

This finding complements Zandbergen's previous research at the DFS site (2016), which provided similar results for laying hens; when the resident Lohman Brown flock was supplied with the same 1:1 spelt:concentrate feed composition, it similarly maintained a laying percentage comparable to the Dutch organic standard (85%). Literature suggests that the laying percentage of hens may be less sensitive to a protein-poor diet than the growth productivity of broilers; after all, the protein requirement of a chicken markedly decreases with maturation (Crawley, 2015) while foraging capacity, vice versa, is affected by learned experience (Almeida et al., 2012; Bassler, 2005; Spencer, 2013). However, the Hubbard broilers in this study proved equally capable in meeting their dietary requirements via complementary foraging activity as the layers previously studied at the DFS site.

Of course, the result outlined above pertains merely to this specific experimental batch, raised under the particular conditions impacting the site at the time of observation. The outdoor period lasted from mid-May to late July and summer temperatures in 2017 were even higher than may be expected, meaning the broilers did not require much energy for thermal regulation. Apart from weather, fluctuations in invertebrate availability may cause the requirement for supplementary feed to vary throughout the year. Invertebrates with a nutritional profile particularly suitable for Galliformes, such as earthworms, are reportedly more abundant from fall to early spring than in summer (Edwards, 1996; ICOPP, 2014). This might, to some extent, compensate for the energy lost to thermal regulation during the colder months. Considering these opposing forces, the relationship between seasonality and FCR is not clear cut; longitudinal research on broilers raised in orchards could shed light on seasonal variance and assess the viability of a protein-poor diet under different conditions.

The fact that the batch A Hubbards reached acceptable slaughter weights around 84 days of age, even though their concentrate feed was substituted by spelt for 50%, suggests they were able to compensate for the protein deficiency in their feed supply by browsing protein rich feedstuffs from the range. Establishing the type and amount of forage chickens consume from the orchard has not been within the scope of this research and warrants further investigation.

As a general note it should be mentioned that the LW's and FCR's recorded after slaughtering rounds are inevitably skewed by the fact that the heaviest broilers, for economic reasons, were always first to be selected for slaughter. In case of the batch A Hubbards this means that the data for day 76 are representative of the population in its entirety, while later data points likely underestimate the potential LW and FCR because the fastest growing individuals were already removed at these points.

5.2 Growth rate and Feed Conversion Ratio: Batch B - restricted diet

For the DFS broilers that received a restricted daily ration, this study found a substantially improved FCR as compared to the Dutch organic average (2.63 after Ellen et al., 2012). The FCR at 90 days of age (1.9) was actually the same as that of the 'New Standard Chicken'; a conventional broiler breed with a slightly expanded life span (49 rather than 40 days), introduced in 2013 and 2014 by Dutch retailers and the chicken industry in response to public concerns about the health repercussions of fast growth genetics (Thornton, 2016).

The Hubbards of Batch B were subjected to the same 1:1 spelt:concentrate diet as batch A, but in limited rather than ad libitum supply. Resultantly, Batch B consumed less feed, yet weight differences between the two batches were negligible. In all likelihood Batch B compensated for the comparative lack in supplementary feed by foraging even more from the range. This finding appears to confirm practitioner observations that restricting supplementary feed can boost forage consumption without diminishing growth (ICOPP, 2015), although, as pointed out above, the actual nutritional value the broilers collected from the orchard was not investigated in this study. Because there were no signs of LW being negatively affected by the dietary treatment (max 45 g concentrate and 35 g of spelt/chick/day), it is quite possible that the broilers could have gained enough nutrition from the orchard to compensate for an even more sober supplementary diet, either in terms of protein content or absolute volume. Further research could investigate at what level of restriction growth levels off and shed light on how forage consumption is affected by different dietary treatments.

Practitioner data suggests that pastured poultry generally eat 5-20% of their diet from pasture (Spencer, 2013). Interestingly, Batch B consumed (2,63 - 1,94 =)0,69 kg less supplementary feed per kg of weight gain than the average Dutch organic broiler, implying that their overall diet may already have included about 26% of forage. Two notable differences between the DFS studied and more commonly found pastured poultry set-ups are (1) that the DFS broilers roam a (highly biodiverse) orchard rather than a pasture and (2) that they are not confined to their pens after 6 weeks of age. In a previously conducted study on orchard-roaming broilers raised under similar conditions, Antonissen & Lantinga (NP) similarly showed that feed-restricted broilers got 28% of their energy requirements from herbage and other feed sources of their outdoor run. Further research might focus on potential differences in nutritional value between varying habitats and the forage intake implications of pen confinement versus free range management.

Unfortunately, the two dietary treatments in this study were implemented in different rearing cycles and comparisons between respective results could not be statistically verified. It is possible that conditions in the orchard were comparatively beneficial during the outdoor period of Batch B (mid-June to late August) and it cannot be assumed that the Hubbards of batch A would have achieved a similarly efficient FCR if their feed supply had been restricted. It appears likely, since outdoor temperatures were favourable during both outdoor periods (which partially overlapped) and within season invertebrate variance may be limited (Edwards, 1996). Even if we assume similar outdoor conditions, the treatments of Batch A and Batch B still differed in that the first remained indoors for 6 rather than 3 weeks. In this context, the improved upon FCR of the Batch B broilers is no less remarkable, considering they were actually subjected to the protein-poor diet (implemented from the onset of the outdoor period) for 3 weeks longer than their predecessors. Nonetheless, as with protein content, further research is warranted to draw any conclusions on how the growth rate and FCR of orchard-roaming broilers respond to absolute feed limitations under differing seasonal conditions. Farmer observation so far suggests that, once temperatures begin to drop in fall, the restricted diet trialled in this study does start to negatively affect growth rates (Pieter Ploeg and Wil Sturkenboom, personal communication).

A final note on diet limitations and broiler welfare: at first glance, the comparatively high mortality rate of Batch B (10% versus a mere 1.3% for batch A) may raise questions as to whether the health of the broilers was compromised by their restricted feed supply. Although unfortunate, the high death rate is largely explained by a local fox frequenting the orchard during the Batch B outdoor period. Although this study did not focus specifically on health indicators, there were no adverse health trends observed in either batch. Other literature similarly suggests that free ranging broilers can subsist on a restricted supplementary ration without incurring negative health effects (ICOPP, 2014), but to what extent of restriction this holds remains unclear. Researchers investigating the outer boundaries to feed restriction would be wise to monitor health systematically, so that experimental animals can be protected from unhealthy nutritional limitations and knowledge may be gained at the same time.

5.3 Cost-return analysis

At respective profit margins of 19% (batch A) and 21% (Batch B), the husbandry of Hubbards in the DFS was clearly economically viable. Although no specific numbers could be found on the profitability of Dutch Organic broiler operations, Agrimatie estimated the margin for the conventional Dutch poultry sector at only 3% for 2017 (“Rentabiliteit vleeskuikens lager”, 2017). Even when taking into account the substantial dispersal around this average – from the lower 20% achieving a revenue-cost ratio of less than 97%, to the upper 20% with a profitability surpassing 109% – the broiler venture at the DFS is remarkably profitable.

However, these results should not be taken out of context. Although the main focus of this study has been Feed Conversion Ratio, a crucial element underlying the economic viability of the DFS is actually direct marketing. Because they sell their meat via their own on-farm channel, the farmers at Fruittuin van West are able to direct 70% of the consumer sales price to their broiler operation; this comes down to €6.97/kg of meat sold. Farmers plugged in to the conventional poultry meat supply chain can only dream of such a farm gate price; in 2017 they received a mere €0.85/kg on average ("Prijsdaling van vleeskuikens", 2017). Although organic farmers receive a premium – data for the Dutch situation is unavailable, but a recent Turkish study (Cobanoglu et al., 2014) estimated organic revenues at 180% of conventional – it seems inconceivable that their farm gate price even approaches €6.97/kg under current market conditions. The unusually high profit margin of 'Kip van West' is thus largely explained by the farmers' independence of the conventional poultry meat supply chain and should not be misinterpreted as a direct result of feed cost savings due to either concentrate substitution or feed supply restrictions.

Furthermore, the economics of the Diversified Farming System are inherently distinct from that of the typical organic broiler farm. Costs are borne by multiple income streams; the broiler range at the Fruittuin van West does not, as usual in organic broiler husbandry (Cobanoglu et al., 2014; Vermeij & Horne, 2008), represent an additional cost for the farmers, but rather a profitable enterprise in its own right. Conversely, the labour costs/kg of meat are relatively high (~€2/kg) because of the additional work involved in feeding and moving several groups of 50 chickens on a daily basis, as compared to the simpler act of feeding one large flock in a stationary stable (Vermeij & Horne, 2008). An exhaustive comparison of the 'Kip van Wests' cost-return structure to that of more typical Dutch organic broiler farms is beyond the scope of this study – the main point is that the results obtained here are highly specific to the farming (and marketing) system at hand. They demonstrate the profitability of organically raising orchard-roaming broilers housed in mobile pens when their meat is sold directly to consumers (at a competitive sales price compared to organic poultry meat prices in Dutch supermarkets). This DFS model clearly shows promise as a side-enterprise for organic orchardists. Additionally, it could inspire mutually beneficial partnerships between orchard holders and poultry farmers; the first providing land access at a favourable rate, in return for the manure and pest and weed control services of the latter's flock.

Although they do not account for the majority of profits, the dietary treatments trialled in this study did improve the bottom-line of the operation. For each kg of concentrate substituted by spelt €0.15 was saved. For batch A this came down to about €0.19 of feed savings/kg of meat. To put that into context; the profit margin for these broilers would have been 17% rather than 19% if they had consumed an equivalent amount of undiluted concentrate. Feed cost savings were even greater for Batch B. Assuming an FCR of 2.63 if the broilers would have been fed ad libitum, the additional cost savings due to their limited diet were about €0.28/kg of meat, resulting in a rise in profit margin from 18% to 21%. Note that the absolute difference in profitability between batch A and Batch B would have been greater if it weren't for the latter's high mortality rate (10% versus 1.3%, a contrast largely explained by fox plunder). Of course, as discussed in the paragraphs above, the cost-effectiveness of the investigated dietary treatments will likely vary throughout the year. Further research is required to assess the full extent to which diets may be restricted either in protein content or absolute supply and how such management choices will affect the financial bottom line throughout the seasons.

A few percent extra profits may actually be most meaningful for broiler businesses facing much tighter margins in the first place. By planting outdoor areas and/or opting for mobile housing, organic poultry farmers could eliminate uneven vegetation pressure (Hermansen et al., 2004; Rivera-Ferre et al., 2006) and facilitate a healthier range ecology that provides more nutritional forage to their birds. Although a professionally run orchard set up in a broiler range could be cost-effective in itself (Bestman, 2015), our results suggest it also has the potential to improve the cost-effectiveness of the resident flock by limiting its feed requirements. As such, it may not just be interesting for orchard holders to welcome poultry farmers on their land, but also for poultry farmers to provide aspiring orchardists with land access – that is: on their range.

5.4 Hubbard versus Vredelinger

One objective of this study was to test whether dual purpose cockerels could be viably integrated in a DFS designed for low input feed requirements and, by extension, compare the economic trade-offs involved in rearing a dual purpose versus a standard organic breed. Unlike the Hubbard rearing cycles, the Vredelinger batch raised in the Fruittuin van West orchard did not provide a positive net income. At a net loss of €128.93, this particular generation of the dual purpose broiler was not economically viable. Costs might have been covered in a less labour intensive system that does not require moving the cockerels, but it is doubtful whether the breed would be able to maintain a similar growth rate on a low-protein diet without the provision of fresh forage on a daily basis.

In fact, even the growth rate found in this trial was not satisfactory to the farmers. The substantial discrepancy in final weight between the Hubbard and the Vredelinger was the main reason for discontinuing the latter; even after 110 days the Vredelingers' average LW (1.29 kg) did not approach the Hubbards' LW at a mere 76 days (1.79 kg). Growth rate was lower than those found in a previous study on the Vredelinger (Havard Dit Duclos, 2017). In this trial the broilers were also housed in a mobile coop and subjected to two different dietary treatments: 100% concentrate and an alternative diet composed for 30% of bread crumbs (bakery leftovers). No significant dietary effects were found and at 97 days of age LW generally hovered around 1,9 kg, while the documented FCR was about 3.9. Since the Vredelingers in this study exhibited a much lower growth rate and a notably less efficient FCR, it seems likely that their feed utilisation efficiency (unlike that of the Hubbards) was negatively affected by the 1:1 spelt:concentrate diet at Fruittuin van West. However, in lack of a control group, the possibility of other determining factors cannot be ruled out.

Since the Vredelinger breed was discontinued before the fifth rearing cycle, its performance on a restricted diet has not been tested. Assuming a Batch B Vredelinger would have achieved similar feed cost savings as the Batch B Hubbard, at no detriment to LW, it would have just about broken even financially. Considering the above, it does seems questionable that this generation of Vredelingers would have been unaffected by further limitations in supplemental nutrition. Nonetheless, a definitive answer to this question warrants further investigation – an interesting line of enquiry for action researchers aiming at the reestablishment of dual purpose chicken breeds.

Future generations of Vredelinger cockerels may prove more viable. The breeding programme is advised to focus efforts on improving the growth rate and FCR of male offspring if it means to establish an economically viable dual purpose breed. Of course, a one-sided quest to optimize these requirements would be beside the point. Optimizing the Vredelingers' foraging capacity may be an interesting alternative strategy to realize feed cost savings for free range poultry farmers – a unique selling point that could actually benefit rather than compromise the health of the broiler.

6. Conclusion

The results of this study suggest that the integration of broiler husbandry into the Fruittuin van West orchard has indeed reduced broiler feed requirements and thereby enhanced its economic and environmental sustainability. Because the broilers were moved a pen-length ahead on a daily basis, they continually had access to fresh forage in the orchard and supplementary feed could be curtailed in terms of both protein content and absolute volume. Neither type of feed limitation compromised FCR and both improved the financial bottom line of the production system.

An ad libitum diet in which concentrate was substituted by spelt for 50% was trialled on both a standard organic breed (Hubbard JA95) and the Vredelinger: the 11th generation of a dual purpose breeding programme. Despite the protein poor diet, the Hubbard achieved an FCR similar to the Dutch organic average. As such, the 1:1 spelt: concentrate diet lowered the environmental and financial costs of feed inputs without detriment to broiler performance. The Vredelinger, however, performed significantly worse ($P<0.05$) both in terms of growth rate and FCR.

In a later rearing cycle another batch of Hubbard broilers was subjected to the same 1:1 spelt:concentrate diet, but on a restricted rather than ad libitum basis. These broilers maintained a similar growth rate to their predecessors, but at a substantially lower feed consumption per kg of weight gain than the Dutch organic average. Their FCR at 90 days of age (1.9) equalled that of the much faster growing breed currently dominating the Dutch broiler production industry. The remarkably efficient feed utilization of this rearing cycle further enhanced the profit margin of the operation, while eliminating the extra environmental impact normally associated with the higher feed requirements of organic production.

Both Hubbard batches were highly profitable at respective profit margins of 19% and 21%. These results demonstrate that organically raising free range orchard-roaming broilers housed in mobile pens can be a lucrative business model – that is, when opting for direct sales to the end consumer and managing the orchard range as a profitable enterprise in its own right. Unlike the Hubbard, the Vredelinger did not turn out profitable within the diversified farming system. Further breeding efforts are required if the Vredelinger is to become an economically viable alternative to specialized broilers. Optimizing the forage capacity of the breed (as opposed to growth rate and FCR) may be a promising alternative breeding strategy to realize feed cost savings for free range poultry farmers, better attuned with the health and welfare demands of the organic market.

Although outcomes will vary under different management and seasonal conditions, these findings clearly demonstrate the potential leaps in efficiency that organic poultry businesses could make if outdoor ranges were purposefully construed (and managed) as valuable sources of nutrition. Opting for a diversified farming system makes sense from this perspective. Organic orchards seem particularly suited to attracting invertebrates nutritional to poultry (ICOPP, 2014) and, conversely, may stand to benefit from the manure and pest- and weed control services of a well-managed flock. The potentially beneficial interrelationships between livestock and agricultural crops are manifold. Further action research along this line of enquiry can help to improve internal resource cycling in agro-ecosystems for the benefit of farmers, animals, human society and the planet we all share.

Figure 10: Kip van West broilers foraging in the Fruittuin van West orchard, generating an additional income stream while benefitting from and to their environment.

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Appendixes

Appendix 1: Average Feed Consumption (FC) Batch A over time

Age (days)	Feed Consumption (kg)	
	Hubbard	Vredelinger
1	0,005	0,003
2	0,016	0,010
3	0,027	0,016
4	0,037	0,023
5	0,048	0,030
6	0,064	0,040
7	0,080	0,049
8	0,101	0,063
9	0,123	0,076
10	0,144	0,089
11	0,165	0,102
12	0,187	0,115
13	0,208	0,129
14	0,229	0,142
15	0,256	0,158
16	0,288	0,178
17	0,320	0,198
18	0,352	0,218
19	0,384	0,237
20	0,416	0,257
21	0,448	0,277
22	0,480	0,297
23	0,512	0,316
24	0,544	0,336
25	0,576	0,356
26	0,608	0,376
27	0,640	0,396
28	0,672	0,415
29	0,704	0,435
30	0,736	0,455
31	0,768	0,475
32	0,800	0,495
33	0,832	0,514
34	0,864	0,534
35	0,896	0,758
36	0,928	0,974
37	0,960	1,108
38	0,992	1,241
39	1,024	1,375
40	1,056	1,599

Age (days)	Feed Consumption (kg)	
	Hubbard	Vredelinger
41	1,088	1,823
42	1,120	1,991
43	1,152	2,051
44	1,184	2,051
45	1,216	2,080
46	1,248	2,169
47	1,280	2,169
48	1,312	2,214
49	1,393	2,245
50	1,526	2,290
51	1,611	2,336
52	1,700	2,381
53	1,801	2,427
54	1,910	2,472
55	2,040	2,533
56	2,157	2,609
57	2,275	2,684
58	2,413	2,745
59	2,546	2,806
60	2,679	2,880
61	2,807	2,941
62	2,943	3,001
63	3,076	3,062
64	3,231	3,123
65	3,360	3,195
66	3,444	3,242
67	3,524	3,287
68	3,596	3,328
69	3,706	3,390
70	3,814	3,451
71	3,922	3,512
72	4,048	3,584
73	4,088	3,609
74	4,160	3,650
75	4,232	3,691
76	4,340	3,752
77	4,503	3,843
78	4,666	3,934
79	4,847	4,010
80	5,010	4,086

Age (days)	Feed Consumption (kg)	
	Hubbard	Vredelinger
81	5,174	4,162
82	5,282	4,238
83	5,445	4,298
84	5,608	4,337
85	5,684	4,362
86	5,777	4,379
87	5,885	4,410
88	5,994	4,457
89	6,087	4,474
90	6,169	4,499
91	6,242	4,524
92	6,351	4,570
93	6,470	4,615
94	6,572	4,640
95	6,682	4,703
96	6,784	4,762
97	6,857	4,803
98	7,016	4,894
99	7,139	4,966
100	7,228	5,021
101	7,378	5,107
102	7,510	5,183
103	7,580	5,368
104	7,660	5,368
105	7,660	5,368
106	7,739	5,412
107	7,819	5,475
108	7,898	5,565
109	7,978	5,654
110	8,057	5,834

Appendix 2: Live Weights (LW) and associated Feed Conversion Ratios (FCR) Batch A at 76, 104, and 110 days of age

Age (days)	Hubbard						Vredelinger	
	Hens		Cockerels		Average		Cockerels	
	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)
76	1,8	2,41	1,90	2,28	1,85	2,35	0,78	4,82
	1,7	2,55	1,80	2,41	1,75	2,48	0,75	5,00
	1,55	2,80	2,00	2,17	1,78	2,45	0,65	5,77
	1,55	2,80	2,10	2,07	1,83	2,38	0,70	5,36
	1,95	2,23	1,95	2,23	1,95	2,23	0,77	4,90
	1,6	2,71	1,65	2,63	1,63	2,67	1,03	3,63
	1,1	3,95	2,00	2,17	1,55	2,80	0,65	5,78
	1,85	2,35	1,90	2,28	1,88	2,31	0,89	4,24
	1,4	3,10	2,20	1,97	1,80	2,41	0,86	4,39
	1,9	2,28	1,95	2,23	1,93	2,25	0,85	4,43
Mean	1,64	2,65	1,95	2,23	1,79	2,43	0,79	4,83

Age (days)	Hubbard						Vredelinger	
	Hens		Cockerels		Average		Cockerels	
	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)
104	2,8	2,74	2,55	3,00	2,68	2,86	1,45	3,70
	2,15	3,56	2,65	2,89	2,40	3,19	1,15	4,67
	1,75	4,38	2,45	3,13	2,10	3,65	1,40	3,83
	1,3	5,89	2,65	2,89	1,98	3,88	1,45	3,70
	2,45	3,13	2,05	3,74	2,25	3,40	1,05	5,11
	2,45	3,13	3,35	2,29	2,90	2,64	1,40	3,83
	2	3,83	1,45	5,28	1,73	4,44	1,45	3,70
	2,4	3,19	3,35	2,29	2,88	2,66	1,05	5,11
	1,35	5,67	2,45	3,13	1,90	4,03	1,20	4,47
	2,2	3,48	2,45	3,13	2,33	3,29	1,30	4,13
Mean	2,09	3,67	2,54	3,02	2,31	3,41	1,29	4,23

Age (days)	Hubbard						Vredelinger	
	Hens		Cockerels		Average		Cockerels	
	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)
110	3,05	2,64	2,90	2,78	2,98	2,57	1,20	4,86
	2,35	3,43	2,10	3,84	2,23	3,44	1,10	5,30
	2,95	2,73	2,65	3,04	2,80	2,74	1,25	4,67
	2,05	3,93	2,75	2,93	2,40	3,19	1,10	5,30
	2,65	3,04	2,80	2,88	2,73	2,81	1,55	3,76
	2,20	3,66	2,65	3,04	2,43	3,16	1,35	4,32
	2,15	3,75	3,40	2,37	2,78	2,76	1,45	4,02
	2,65	3,04	3,40	2,37	3,03	2,53	1,20	4,86
	1,75	4,60	2,65	3,04	2,20	3,48	1,45	4,02
	2,45	3,29	3,50	2,30	2,98	2,57	1,20	4,86
Mean	2,43	3,32	2,88	2,80	2,65	2,93	1,29	4,60

Appendix 3: Average Feed Consumption (FC) Batch B over time

Age (days)	FC (kg) Hubbard
1	0,005
2	0,010
3	0,021
4	0,031
5	0,042
6	0,058
7	0,079
8	0,101
9	0,122
10	0,143
11	0,165
12	0,186
13	0,207
14	0,229
15	0,256
16	0,288
17	0,320
18	0,352
19	0,385
20	0,406
21	0,433
22	0,465
23	0,499
24	0,536
25	0,573
26	0,611
27	0,648
28	0,694
29	0,741
30	0,788
31	0,835
32	0,872
33	0,888
34	0,918
35	0,947
36	0,981
37	1,016
38	1,052
39	1,087
40	1,112

Age (days)	FC (kg) Hubbard
41	1,151
42	1,186
43	1,206
44	1,235
45	1,266
46	1,291
47	1,317
48	1,352
49	1,387
50	1,417
51	1,451
52	1,515
53	1,584
54	1,652
55	1,712
56	1,780
57	1,849
58	1,952
59	2,002
60	2,092
61	2,155
62	2,241
63	2,331
64	2,421
65	2,511
66	2,601
67	2,691
68	2,781
69	2,871
70	2,961
71	3,051
72	3,141
73	3,231
74	3,321
75	3,411
76	3,501
77	3,591
78	3,681
79	3,771
80	3,861

Age (days)	FC (kg) Hubbard
81	3,951
82	4,028
83	4,118
84	4,208
85	4,298
86	4,370
87	4,460
88	4,537
89	4,627
90	4,627

Appendix 4: Live Weights (LW) and associated Feed Conversion Ratios (FCR) Batch B at 78 and 90 days of age

Age (days)	Hubbard					
	Hens		Cockerels		Average	
	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)
78	1,95	1,89	1,75	2,10	1,85	1,99
	1,6	2,30	1,80	2,05	1,70	2,17
	1,15	3,20	1,95	1,89	1,55	2,37
	1,55	2,37	2,00	1,84	1,78	2,07
	1,75	2,10	2,35	1,57	2,05	1,80
	1,55	2,37	1,65	2,23	1,60	2,30
	1,35	2,73	1,95	1,89	1,65	2,23
	1,75	2,10	2,25	1,64	2,00	1,84
	1,65	2,23	2,05	1,80	1,85	1,99
	1,65	2,23	1,95	1,89	1,80	2,05
	1,60	2,35	1,97	1,89	1,78	2,07

Age (days)	Hubbard					
	Hens		Cockerels		Average	
	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)	LW (kg)	FCR (kg FC/kg LW)
90	2,5	1,85	2,00	2,31	2,25	2,06
	2,6	1,78	3,15	1,47	2,88	1,61
	2,2	2,10	2,85	1,62	2,53	1,83
	2,6	1,78	2,50	1,85	2,55	1,81
	2,05	2,26	2,95	1,57	2,50	1,85
	1,75	2,64	2,30	2,01	2,03	2,28
	2,15	2,15	2,30	2,01	2,23	2,08
	2,3	2,01	2,20	2,10	2,25	2,06
	2,25	2,06	2,45	1,89	2,35	1,97
	2,1	2,20	2,45	1,89	2,28	2,03
	2,25	2,08	2,52	1,87	2,38	1,94

Appendix 5: Nutritional details of van Gorp ECO vleeskuikenmeel 1

Complete feed for broiler chicks up till 6 weeks of age. Permitted in organic agriculture. (Bio control NL-Bio-01; Skal 001231; registrationnumber NL20119)

Nutritional constituents (%)	
Crude protein	20.7
Crude fat	5.2
Crude cell substance	5.3
Crude ashes	6.2
Calcium	1.05
Phosphorous	0.55
Sodium	0.15
Methionine	0.38
Lysine	1.02

Nutritional supplements / kg	
Vitamin A	10000 IE
Vitamin D3	3000 IE
Vitamin E	50 mg
Iron(II) sulphate monohydrate	70 mg
Calcium iodide	1 mg
Copper(II) sulphate pentahydrate	10 mg
Manganese(II) sulphate	60 mg
Zinc sulphate monohydrate	50 mg
Sodium selenite	0.35 mg

Ingredients
Wheat Organic
Maize Organic
Soy scatter Organic Fairtrade
Sunflower scatter Organic
Pea Organic
Rape scatter Organic
Maize gluten flower 59
Potato protein
Sesame scatter Organic
Chalkstones
Premix
Brewer’s yeast
Soy oil Organic
Monocal phosphate
Lactic acid

Sourcing (%)	
Organic agricultural	95
of which in conversion	0
Non-organic agricultural	5
Agricultural	95.6

Appendix 6: Nutritional details of van Gorp ECO vleeskuikenmeel 2

Complete feed for broiler chicks from 6-12 weeks of age. Permitted in organic agriculture.
(Bio control NL-Bio-01; Skal 001231; registrationnumber NL20119)

Nutritional constituents (%)	
Crude protein	19.2
Crude fat	5.2
Crude cell substance	5.6
Crude ashes	7.1
Calcium	1.05
Phosphorous	0.53
Sodium	0.17
Methionine	0.35
Lysine	0.92

Nutritional supplements / kg	
Vitamin A	10000 IE
Vitamin D3	3000 IE
Vitamin E	50 mg
Iron(II) sulphate monohydrate	70 mg
Calcium iodide	1 mg
Copper(II) sulphate pentahydrate	10 mg
Manganese(II) sulphate	60 mg
Zinc sulphate monohydrate	50 mg
Sodium selenite	0.35 mg

Ingredients
Wheat Organic
Maize Organic
Soy scatter Organic Fairtrade
Sunflower scatter Organic
Pea Organic
Triticale o/s
Sesame scatter Organic
Potato protein
Rape scatter
Maize gluten flower 59
Chalkstones
Premix
Clinoptilolite Ig568
Soy oil Organic
Lactic acid
Monocal phosphate
Salt

Sourcing (%)	
Organic agricultural	95
of which in conversion	4
Non-organic agricultural	5
Agricultural	95.1