Assessing the water footprint of poultry meat

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Purpose: *This paper seeks to evaluate the methodology used in the determination of the water footprint of poultry meat and identify the production variables that can have an impact on water footprint.*

Design/methodology/approach: *The first stage of the research involved an examination of literature. The second stage involved comparing data obtained from an industry based research study with literature derived data.*

Findings: *The research has shown that the degree of intensity of livestock production systems will have an impact on the ecological footprint of the final food product. Key parameters that will impact on the virtual water content of poultry meat include bird age, bird weight, feed conversion rate (FCR) and mortality levels. It is also important to relate virtual water to calorific value as this will be a key measure in providing information on the value of virtual water in terms of human food production.*

Originality/Value: *This research is of academic value and of value to those working in the food supply chain.*

Limitations of the Study*: The research was undertaken using data derived from industry rather than an experimental research site.*

Category*: Research Paper*

Key words*: water, footprint, virtual, methodology, poultry, calculation*

1. Introduction

Essentially, agriculture takes items of little or no calorific value such as seeds, soil and water and turns them, using solar energy and animal metabolism, into calories that are accessible to humans as food (Manning, in press). Food products have varying ecological footprints depending on the efficiency of the particular path of conversion, but agriculture is essentially the "process" of producing calories and key nutrients for people. The term "water footprint" describes the extent of personal water use in relation to consumption (Hoekstra and Chapagain, 2006). However, the term can be extended to represent the demand for water resources by a family, community, nation or indeed in a global context. The total amount of water that is used in the "production" of a good is termed the "*virtual water*" content (van Hofwegen, 2007). The author determined that the virtual water content of wheat is 1 m^3/kg whereas the virtual water associated with meat production can vary between 5 and 13.5 m^3/kg. Further research supported this by suggesting that the virtual content of wheat and barley is 1.3 m^3/kg, poultry meat 3.9 m^3/kg, sheep meat 6.1 m^3/kg and beef 15.5 m^3/kg (Waterfootprint, 2009; *Manning et al.,* 2008a). The virtual water content and the calorific content have been compared for a range of foods (Table 1). The results demonstrate that the calorie: virtual water ratio for bread is the same as cheese and the calorie: virtual water ratio for rice is nearly half that of potatoes. Therefore if food policy is driven by calories per volume of virtual water used rather than virtual water content only this would change the perspective on the environmental impact of a given food product highlighting that determining water footprint in terms of virtual water content alone without considering the calorific value of food is a rather simplistic argument. However, this is one of the measures that is currently being used as a means of determining the environmental impact of food production. The water footprint (virtual water content) of a range of products has been calculated (Table 2). These calculations are largely derived from the work of Chapagain and Hoekstra (2004) who developed a series of equations to determine virtual water of foodstuffs including live animals, primary crops and processed crops and livestock products.

Table 1: The calorific value: virtual water ratio for a range of foods

Food Item	Calorific value (kCal/100g)[1]	Virtual water content (L/100g)[2]	Calorific value: virtual water content ratio
Beef (ground)	332	1600	1: 4.8
Bread	266	133	1: 0.5
Cheese (cheddar)	403	500	1: 1.2.
Chicken meat (deboned)	216	390	1: 1.8
Potatoes	77	90	1: 1.2
Rice	365	340	1: 0.9

[1]USDA (2008) [2] www.waterfootprint.org

Table 2: The water footprint of consumer products

Product	Virtual water content (litres)
1 cup of tea (250ml)	35
1 slice of bread (30g)	40
1 apple	70
1 cup of coffee (125ml)	140
1 glass of milk (200ml)	200
chicken meat (100g)	390
cheese (100g)	500
beef (100g)	1600
1 hamburger (150g)	2400
1 cotton T-shirt (medium sized, 500g)	4100
1 pair of shoes (bovine leather)	8000
1 pair of jeans (1kg)	11000

(Source: www.waterfootprint.org)

The impact of cereals on water footprint calculations is identified not only in terms of direct foodstuffs such as wheat, flour, bread, biscuits, cakes, but also as one of the main constituent of animal feeds. Using wheat data, (Table 3) it can be demonstrated for five countries analysed that the crop water requirement varied from 179 – 630 mm/crop period with the average virtual water content of 1334 m^3/tonne with a range of 738 – 1588 m^3/tonne. This showed a wide variation in virtual water content depending on the region where the wheat is grown and is a function of the natural environment and the yield. Research from the Australian Wheat Board (AWB, 2008) determined the degree of variance from season to season in terms of yields per hectare (Table 4).

Table 3: Virtual water content of wheat by country

Country	Crop water requirement (mm/crop period)	Wheat yield (tonne/ha)	Virtual water content (m^3/tonne)
Argentina	179	2.4	738
Australia	309	1.9	1 588
Canada	339	2.3	1 491
France	630	7.0	895
US	237	2.8	849
Global average (all countries)		2.7	1 334

(Source: www.waterfootprint.org)

Whilst one source calculated that the average wheat yield in Australia is 1.9 tonnes/hectare (waterfootprint.org, 2009) the AWB (2008) for the years 2000 - 2005 defined an average of 1.7 tonnes/hectare with a range of 0.91 – 2.11 tonnes/hectare.

Table 4: Australian wheat yield 2000 - 2005

Season	Wheat yield (tonne/ha)						
	NSW & ACT	**VIC**	**SA**	**WA**	**QLD**	**TAS**	**Australia**
2000 – 01	2.14	2.69	2.11	1.30	1.31	3.71	1.82
2001 – 02	2.33	2.46	2.40	1.78	1.49	4.17	2.11
2002 – 03	0.83	0.72	1.06	1.91	1.17	3.57	0.91
2003 – 04	1.83	2.23	1.78	2.25	1.41	3.19	2.00
2004 - 05	2.06	1.49	1.33	1.62	2.00	2.67	1.70
Average							1.71

(Source: AWB, 2008)

North *et al.,* (2008) in their research on water usage and wheat yields concluded that wheat in the Australian Murray-Darling basin received median growing season rainfall of 250mm; crops were pre-irrigated in autumn 100 - 150mm; and spring irrigations applied 60 to 75mm i.e. a crop requirement of 410mm – 475mm. The authors further proposed that the total depth of water applied (on top of seasonal rainfall) to each plot varied from 300 to 600 mm and the yield varied between 4.8 and 7.3 tonnes/hectare. This data identified the impact of specific farming practices on virtual water content. It could therefore be argued that the development of virtual water content calculations, in an effort to determine the environmental impact of foodstuffs, is actually a form of benchmarking or a tool for comparing the ecological footprint of different production systems. Manning *et al.,* (2008b) argued that the key to effective benchmarking is to determine whether the tool will be utilised at a strategic management level or at an activity or enterprise level i.e. either as a whole supply chain or at individual stages within the supply chain. Furthermore, in supply chains with multiple suppliers, manufacturers, distributors and retailers, that can interact on either a global, national or local basis, performance measurement is "challenging" because it can be difficult to attribute performance results to one particular unit within the supply chain (Hervani *et al.,* 2005). The wheat example demonstrates that whilst averaged data can be used to assess virtual water content it has to be treated with caution in terms of developing national or organisational policy or indeed with regard to product labelling as there is such a range of variants including specific farm practice, intra-national location as well as national location.

Segal and Macmillan (2009) recommended that a "*water stewardship approach offers the best basis for addressing water issues within a multi-criteria sustainability label.*" They proposed a form of organisational or supply chain benchmarking as previously described. Further the authors concluded that many businesses, non-governmental organisations (NGOs), academics and agencies have been resisting pressure to introduce water footprint or even water-impact based labels. The approach to water sustainability becomes more complex because different types of freshwater can also be classified within water footprint terminology. Rainwater that falls on a watershed can be theoretically divided into "green" and "blue" water (Yang *et al.,* 2006). Yang *et al.,* (2006) defined green water as "*the return flow of water to the atmosphere as evapo-transpiration (ET) which includes a productive part as transpiration (T) and a non-productive* *part as direct evaporation (E) from the surfaces of soils, lakes, ponds, and from water intercepted by canopies or the water stored in the unsaturated soils*". This type of water is the source for rain-fed food production. In contrast the term "blue" water describes "*the water in rivers, lakes, reservoirs, ponds and aquifers*" and this is the main source of water for crop irrigation (Yang *et al.,* 2006). The term given to water that is recycled or reprocessed is "grey" water. In 2007, the UK Department for the Environment, Food and Rural Affairs (Defra) published a research report entitled "A review of recent developments in, and the practical use of, ecological foot printing methodologies". The report was developed by Risk & Policy Analysts (2007) and determined that "*data and methodological issues associated with the calculation of national footprints remain. Identified data issues include: concerns regarding the quality of source data; and the fact that there no indication is given of the levels of uncertainty associated with data."* The report further argued that "*Stakeholders using ecological footprints have expressed uncertainty about the range of methods available to them ..... and the appropriateness of their use in different situations*".

De Fraiture *et al.,* (2004) reviewed whether international cereal trade saves water as a means to determine the impact of virtual water trade on global water use. The authors concluded that whilst virtual water trade has the potential to reduce water use, policy makers should be cautious as to whether virtual water trade will play a significant role in managing global water resources into the future. They argued that trade does not occur because of water shortages and that most trade occurs between countries with abundant natural resources. Further they stated that "*not all water "savings" can be reallocated to other beneficial uses .... reductions in global water use relate to productivity differences between importers and exporters rather than water scarcity [and] .. political and economic considerations—often outweighing water scarcity concerns [and] .. limit the potential of trade as a policy tool to mitigate water scarcity*". It is within this context that the research reported in this paper has been undertaken.

2. Determining virtual water content

Zimmer and Renault (2003) argued that in the formulation of virtual water methodologies a number of assumptions are made and different accounting procedures used. They identified five steps that need to be considered namely to categorise food products with regard to processes and their virtual water value; properly map the fluxes of products within and at boundaries of the systems considered; specify the production process for each type of food product; specify the scope of the study; and compute virtual water content and flows. Hoekstra (2003) stated that it was difficult to assess the virtual water content of a product because of the number of influencing factors that affected the amount of water used in a production process. He suggested that the following factors should be considered: the place and period (e.g. which year, which season) of production and the point of measurement. With regard to irrigated crop production, water use at the point of water withdrawal or at the field level should be determined as well as the production method and the associated efficiency of water use. The inclusion or exclusion of waste water should also be identified in the methodology. The method of attributing water inputs into intermediate products to the virtual water content of the final product should also be defined. This makes the determination of the virtual water content of a product both location and process specific and focuses on the efficiency of the processes employed.

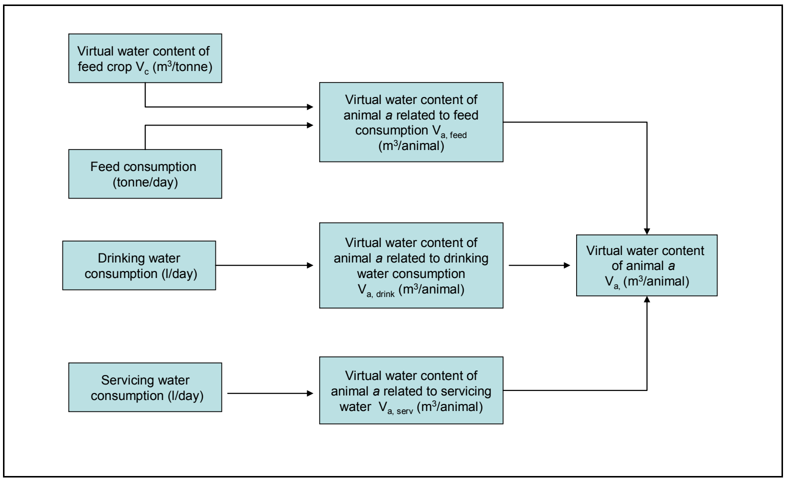
Zimmer and Renault (2003) identified three efficiencies that need to be considered: water efficiency i.e. irrigation efficiency and the reduction in water quality following multiple uses; production efficiency; and consumption efficiency which considered the levels of waste. Segal and MacMillan (2009) argued that it is not just the volume of water used to produce the product that is important, rather how that volume of water relates to the volume that is available. They concluded that whilst water footprinting is a tool that is often used for measuring water use it has its limitations namely that it does not focus on water efficiency and there is a lack of consensus on methodology. Segal and MacMillan further suggested that the process does not embed social and ethical considerations and does not identify opportunity costs for water savings.

With specific focus on poultry meat production, the virtual water content of an animal at the end of its life span has been defined "*as the total volume of water that was used to grow and process its feed, to provide its drinking water, and the water used during the production cycle*" Chapagain and Hoekstra (2004). It will vary according to the type and breed of the animal, the farming system used, water consumption, feed consumption, feed conversion rate, the water used in producing the feed, and the climatic conditions of the place where the feed is grown. Chapagain and Hoekstra (2004) defined three components to the virtual water content V_a of a live animal *a*:

$$V_a = V_{a,feed} + V_{a,drink} + V_{a,serv}$$

where $V_{a,feed} + V_{a,drink} + V_{a,serv}$ represent the virtual water content of an animal *a* related to feed, drinking water and service water consumption respectively, expressed in cubic metres (m^3) per live animal (Figure 1).

Figure 1: Virtual water content of a live animal (Adapted from Chapagain and Hoekstra, 2004)



The virtual water content of a crop *c* (m^3/tonne) has calculated as the ratio of the total volume of water used for crop production, U_c (m^3) to the volume of crop produced Y_c (tonne).

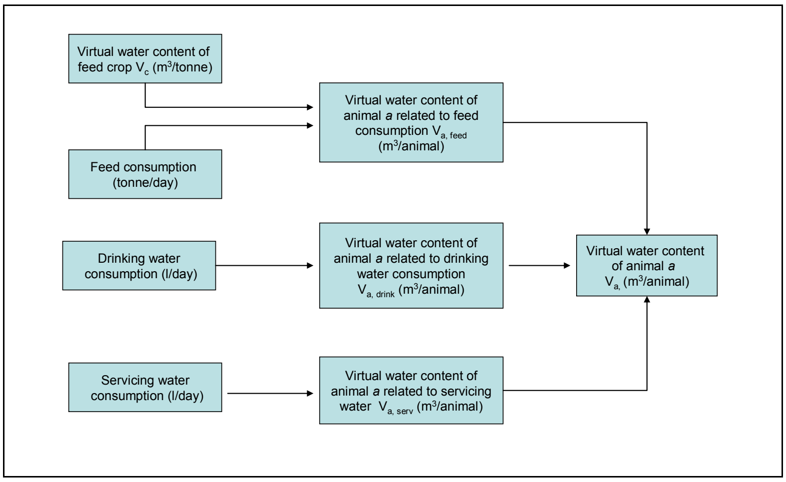
$$V_c = \frac{U_c}{Y_c}$$

The average virtual water content of a crop c in a country, $V_{c,n}$ (m^3/tonne) is calculated as the ratio of the total volume of water used for the production of crop *c* (U_c) to the total volume of crop produced in that country. The total volume of water used for the production of crop U_c, is calculated as:

$$U_c = R_c \times A_c$$

where A_c is the total harvest area (ha) of a crop *c* in a country and R_c is the crop water requirement (m^3/ha) for the entire growth period of a crop c. It is usually assumed in these calculations that the crop water requirement is fully met either by irrigation or by rainfall (see Figure 2).

Figure 2: Virtual water content of a crop (Adapted from Chapagain and Hoekstra, 2004)



Having developed these equations, Chapagain and Hoekstra (2004) determined that the virtual water content of a processed product relates to the virtual water content of the primary crop or live animal from which it is derived. The virtual water content of the primary crop or live animal is distributed over the different products from that specific crop or animal. This makes the calculations more complex. The products derived from a primary crop or live animal are called primary products e.g. poultry primary products are meat or eggs. Some of these primary products are further processed into secondary products. The virtual water content of a processed product from a primary crop or a live animal includes the element of the virtual water content of the primary crop or live animal plus the processing water needed. The processing water requirement is calculated as follows:

$$R_{proc} = \frac{Q_{proc}}{X_{proc}}$$

where R_{proc} is the processing water requirement per ton of primary crop *c* or live animal *a* for processing primary products (m^3/tonne). Q_{proc} is the volume of processing water required (m^3) to process crop *c* or animal *a*. X_{proc} is the total weight of the primary crop or live animal processed. It is important to ensure that the virtual water content attributed to the final product takes into account the actual yield of the product at the end of processing compared to the live weight or gross weight of the crop or animal prior to processing.

4. Methodology

The aim of the study was to determine the virtual water content of poultry meat in a specific production process on farm and compare to published figures. This methodology has been used previously by Dawkins et al., (2004) when studying the influences on poultry welfare in housed birds. The objectives were to identify:

- The virtual water content of the live animals in terms of the total volume of drinking water;
- The virtual water content of the live animals in terms of the total volume of water that was used during the production cycle;
- The virtual water content of the live animals in terms of the total volume of water that was used to grow and process the feed;
- Compare this data to existing published data; and
- Determine the factors that can affect virtual water content and their degree of influence at this food production stage.

The primary data was sourced from twelve poultry production sites and supported by data in published literature. The study involved 10.6 million birds and sixty-five growing cycles (crops) were analysed in the benchmarking window from June 2004 until December 2005. This compares with 2.7 million birds in the Dawkins *et al.,* (2004) study. The range of average crop length (including fallow period) for the sites was 7.00 – 8.74 weeks with a median of 8.29 weeks. The birds studied were both Ross 308 and Cobb 500, but predominantly the Ross breed. The sites were working to three differing programmes:

1. A 52 day programme (excluding fallow period) with sexed birds in two pens per house with a thinning stage at 38 days when the pullets are depopulated;
2. An as-hatched programme when the birds are all depopulated aged 39 – 42 days depending on weight; and
3. Sites which were working to both programmes within the 12 month benchmarking window.

The data were collected using a structured checklist that was sent out to the participating sites. The data collection process was developed within the following study constraint i.e. that the primary data was provided by commercial poultry sites rather than within the controlled conditions of poultry research sites. However this means that the data reflects the commercial situation. Descriptive statistics have been used namely the arithmetic mean, median, range and the inter quartile range as a measure of spread for quantitative variables. Variation and dispersion of data were analysed using standard deviation, and r, the correlation coefficient.

5. Results

5.1 Water consumption

Water intake by birds will depend on a number of factors including breed and age, animal health and well-being, feed composition, water temperature and water quality and drinking system used (Cobb 1995, Ross 1999). The factors that affect water consumption in poultry have been discussed by Manning *et al.,* (2007a). Manning *et al,* (2007b) determined that the mean water consumption for all sites (n = 12) was 7.46 L/bird/cycle (SD 1.21, IQR 6.30-8.50); the mean water consumption for all crop cycles (n = 51) was 7.70 L/bird/cycle (SD 1.31, IQR 6.36 – 8.80). The water consumption range of 5.58-9.62 L/bird/cycle complied with the IPPC BREF (2003) standard of 4.5 - 11 L/bird/cycle (Table 5). The data from the benchmarking group was analysed for Group 1 (sites growing with a sexed programme with a mean bird weight of 2.74 Kg) mean water consumption = 8.68 L/bird per cycle (SD 0.50, IQR 8.47-8.75) and Group 2 (sites growing with an as-hatched programme to a mean bird weight of 2.18 Kg) mean water consumption = 6.39 L/bird per cycle (SD 0.55, IQR 6.11-6.56). The two groups were compared using sem and there was a statistically significant difference between the two groups (p = 0.05).

Table 5: Benchmarking data for poultry water consumption

<table>
<tr><th></th><th>Defra (2004)</th><th>IPPC BREF (2003)</th><th>AUS (2000)</th><th>Chapagain and Hoekstra (2003)</th><th>Research Data</th></tr>
<tr><td>Water consumption (L/head per day/1000)</td><td>15 –30</td><td></td><td>180 – 320</td><td>280</td><td>152 - 166</td></tr>
<tr><td>Water consumption (L/head per cycle) 42 days</td><td>0.63 – 1.26</td><td>4.5 – 11</td><td>7.6 – 13.4</td><td rowspan="2">19.6</td><td>6.39</td></tr>
<tr><td>Water consumption (L/head per cycle) 52 days</td><td>0.78 – 1.56</td><td>4.5 – 11</td><td>9.4 - 16.6</td><td>8.68</td></tr>
</table>

Note Chapagain and Hoekstra is based on a 70 day age

Therefore, when determining water consumption, and its impact on virtual water content of the meat the type of production system must be taken into consideration. The research also demonstrated that water consumption was related (p = 0.05) to crop length (r = 0.80), feed usage (r = 0.86) and average weight (r = 0.92) see Manning *et al.,* 2007b). The analysis of total water consumption demonstrated variance by site, by group and by season and each site had a different water consumption profile in terms of l/bird per cycle. The data from the Chapagain and Hoekstra 2003 study was based on a 70 day production cycle. This is not indicative of a commercial intensive poultry meat production operation as was researched in the empirical study.

5.2Water used for terminal hygiene

The results from the forty six crops was analysed and the mean volume of water used for all crops was 0.010 m^3/m^2 (SD 0.006, IQR 0.006 – 0.011). This complies with the IPPC BREF (2003) benchmark of 0.002 – 0.020 $m3/m^2$. The water used for terminal hygiene per bird, or per kg liveweight, will relate to stocking density in terms of $birds/m^2$; and/or kg/m^2. The stocking density was not defined in the Chapagain and Hoekstra study, but the commercial research data was a factor of ten lower (Table 6). However, this will have very little impact though on the overall virtual water content of the poultry meat.

Table 6: Benchmarking data for water for servicing (cleaning)

	IPPC BREF (2003)*	**Chapagain and Hoekstra (2003)**	**Research Data***
Water usage (m^3/m^2)	0.002 – 0.020		0.006 – 0.011 Average (0.01)
Water usage m^3/bird (*Based on 18 birds/m^2)	$1.1 \times 10^{-4} – 1.1 \times 10^{-3}$	9.8×10^{-3}	5.5×10^{-4}

5.3 Feed conversion rate (FCR)

FCR is a measure of feed efficiency. Feed efficiency of broilers is affected by bird age, sex, health and environmental temperature although the major factor is usually dietary energy concentration (Leeson, 2002). The mean FCR for all sites (n = 12) was 1.81 (SD 0.03, IQR = 1.79 – 1.82) and for all crops (n = 63) was 1.81 (SD 0.06, IQR = 1.76 – 1.85). The data from the benchmarking group has been analysed for Group 1 (mean crop length = 8.74, mean FCR = 1.81, SD = 0.06, IQR = 1.76 – 1.85) and Group 2 (mean crop length = 7.13, mean FCR = 1.80, SD = 0.06, IQR = 1.75 – 1.85). Ross (2006) defined both FCR and average weight benchmarking figures for the Ross 308 (Table 7). The results indicate that although the groups had very similar results neither were meeting the predicted FCR for bird age.

Table 7: Ross 308 performance figures for FCR and Average Weight

	Ross 308 42 day as hatched	**Ross 308 38 day female**	**Ross 308 52 day male**	**Research 42 day**	**Research 52 day**	**Chapagain and Hoekstra (2003)**
Feed consumed (kg/bird)				3.94	4.96	6.97
FCR	1.72	1.68	1.83	1.81	1.76	3.18
Average Weight (kg)	2.47	1.97	3.57	2.18	2.74	2.20

(Source: Ross Breeders, 2006)

The difference in average FCR between groups was calculated as 0.01. This was much smaller than expected and could have been due to the variance in feed specification or growing standards. The average weight for the Group 2 birds was lower than expected so this could therefore explain the poorer FCR. The IQR suggested variation between growing sites and this was also probably due to bird age on depletion. The FCR in the Chapagain and Hoekstra study was 3.18 compared to the commercial crop of 1.81. As the FCR i.e. the amount of food consumed per kg of bird weight plays such a huge part of the virtual water content of the poultry meat such variations from optimum production will have a major impact on the final calculations of virtual water content.

5.4 Average weight

The mean bird weight for all sites (n = 12) was 2.47 kg (SD 0.28, IQR 2.15 – 2.70) and the mean bird weight for all crops (n = 64) was 2.50 kg (SD 0.30, IQR 2.16 – 2.72). The data from the benchmarking group has been examined for Group 1 (mean bird weight = 2.74 kg, SD = 0.10, IQR = 2.68 – 2.79) and Group 2 (mean bird weight = 2.18 kg, SD = 0.04, IQR = 2.11 – 2.17). Ross Breeders (2006) define average weight benchmarking figures for the Ross 308 (Table 7). The results indicate that neither study group was meeting the predicted average weight nor the FCR for bird age. There was a statistically significant difference (using sem) between the two sets of data demonstrating that the groups were growing to distinct bird depletion weights ($\rho < 0.05$).

5.5 Total mortality

The mean total mortality for all sites (n = 12) was 3.00% (SD 0.61, IQR 2.77 - 3.38) and for all crops (n = 65) was 3.08% (SD 0.97, IQR 2.42 – 3.67). Defra (2004) define an average mortality rate of 10%; Heier *et al.,* (2002) 4.42% at 42 days; Sheppard and Edge (2006) 4.1%; and in the study undertaken by Dawkins *et al.,* (2004) the mean total mortality was 4.1% with a range of 1.4 – 14.7. Heier *et al.,* (2002) in their research on mortality in Norwegian broiler flocks concluded that the average weekly cumulative mortality was 1.54% during the 1st week and 0.48% per week during the rest of the crop. Mortality has not been included in the Chapagain and Hoekstra model and should be included in a future refinement of the methodology as it has the potential to greatly impact on the virtual water content of the poultry meat as is demonstrated by the range identified by Dawkins *et al.,* (2004).

The standard calculation on which much of the current water footprint literature is based i.e. 3900 m^3/tonne of poultry meat. However, Chapagain and Hoekstra (2003) determined that the meat from animals grown in different systems had a distinct virtual water content. The more intensive the poultry production systems the lower the virtual water content of the live animal and the resultant meat produced (Table 8). The virtual water content of the grazing system is 7.5 times that of the intensive system and the virtual water content of the extensive system was 26% of that stated for live poultry production.

Table 8: Comparison of the virtual water content of live poultry birds from different production systems

System	Virtual water content of live poultry birds (m^3/tonne)	Calorific value: virtual water content ratio
Grazing system	7702	1: 3.6
Mixed system	2695	1: 1.2
Intensive system	1028	1: 0.5
World average	1498	1: 0.7
Water footprint stated	3900	1: 1.8

(Adapted from Chapagain and Hoekstra, 2003)

The determination of the virtual water attributed to the feed has been undertaken using the Chapagain and Hoekstra data because the exact specification of the feeds used on the farms involved in the commercial research was confidential and not released as part of the study.The results for the virtual water content of the meat produced by the 42 day and 52 day programme has been collated (Table 9). This demonstrates that the 52 day programme results are on a par with those obtained by Chapagain and Hoekstra (2003) for the intensive programme at 1059 and 1028 m^3/tonne respectively. The difference in ten days of the growing programme alone has an impact on the virtual water content of the meat at 1330 m^3/tonne.

The research undertaken highlighted the range of variables that can have an impact at a production level for both crop and livestock production. This makes the determination of virtual water content both process and production system specific. Therefore the methodology is more complex than that previously described in the literature. For example, the current methodology for poultry meat does not include the volume of water used in processing the carcase. However this would only make a minor contribution compared to feed conversion. A further factor that will have a significant impact on the calculation of virtual water content is mortality.

Table 9: Comparison of the virtual water content of poultry meat in the research study

	Research 52 day	**Research 42 day**	**Chapagain and Hoekstra (2003)**
Live weight	2.74	2.18	2.20
Product fraction (0.73)	2.00	1.59	1.60
Water from drinking (m^3/bird)	0.009	0.006	0.02
Water from servicing (m^3/bird)	0.00055	0.00055	0.01
Water from feed (m^3/bird)	2.11	2.11	2.96
Water from drinking (m^3/tonne)	3.13	2.75	9
Water from servicing (m^3/tonne)	0.19	0.25	4
Water from feed (m^3/tonne)	771	968	1344
Virtual water content of live weight (m^3/tonne)	774	971	1867
Virtual water content of poultry meat (m^3/tonne)	1059	1330	2558

According to Dawkins *et al.,* (2004) mortality can vary across the production systems that they studied by as much as 1.4% to 14.7%. Indeed, health and welfare of the animals themselves plays a key role in influencing the ecological footprint of livestock production.

6. Conclusion

The environmental footprint of consumer behaviour is gaining widespread interest as well as the requirement for environmental or "eco-labelling". In order for consumers to make informed choices objective and meaningful data needs to be available and transparent. The research has shown that the degree of intensity of livestock production systems will have an impact on the ecological footprint of the final meat product. Key parameters that will impact on the virtual water content of poultry meat include bird age, bird weight; feed conversion rate (FCR) and mortality levels and these indicators need to be incorporated into organisational and supply chain ecological footprint models. Given this context, it makes the process of eco-labelling for water footprint especially difficult. The ratio of virtual water to calorific value is little discussed at present in the literature, but ultimately will be the main parameter that will provide information on the value of virtual water in terms of human food production and associated water policy.

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