Predictors of dead on arrival (DOA) among broilers slaughtered at a poultry abattoir in Mopani District of Limpopo Province, South Africa.

By

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In

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Dedication

I dedicate this work to my Lord the Great Lion King of Judah, my wife Sonia Matumelo Shokwe, my parents (Mr Ben and Mrs Irene Shokwe) and my siblings (Amelia, Tebogo and Thapelo) who have always encouraged me to be the best version of myself by working hard.

Declaration

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I declare that this dissertation is my own unassisted work and that I have acknowledged sources of references I have used.

27 October 2020

Signature | Date

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List of acronyms

AIC	AKAIKE'S INFORMATION CRITEREON
°C	DEGREES CELSIUS
CI	CONFIDENCE INTERVAL
DOA	DEAD ON ARRIVAL
FAWC	FARM ANIMAL WELFARE COMMITTEE
IBM	INTERNATIONAL BUSINESS MACHINES
IRR	INCIDENCE RATE RATIO
IQR	INTERQUARTILE RANGE
KG	KILOGRAM
KM	KILOMETRE
LM	LOCAL MUNICIPALITY
RR	RATE RATIO
SADC	SOUTHERN AFRICAN DEVELOPMENT COMMUNITY
SE	STANDARD ERROR
SPSS	STATISTICAL PACKAGE FOR SOCIAL SCIENCES
USA	UNITED STATES OF AMERICA
VIF	VARIANCE INFLATION FACTOR

Manuscripts and presentations arising from this dissertation

- Manuscript
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Abstract

Dead-on-arrival (DOA) at poultry abattoirs is a significant problem faced by poultry producers and abattoirs and causes losses of billions of rands each year. However, the phenomenon of DOAs has not been extensively investigated in South Africa. The aim of this study was to investigate the trend in the proportions of DOAs and factors associated with DOA counts among chickens slaughtered at a commercial abattoir in the Mopani district in Limpopo, South Africa. In this study, secondary data of broilers slaughtered at an abattoir between January 2014 and December 2016 was used to assess the temporal trend of DOA counts and factors associated with DOA counts. A negative binomial model was fit to the data to investigate the association between predictor variables (i.e., years, seasons, biosecurity, capacity, distance travelled, birds' average mass and farm rejected) and the outcome variable (DOA counts). The percentage of DOA counts recorded over the study period was 0.48%. The highest proportion of DOAs were observed during the summer months (0.77%; 95% CI: 0.7695 - 0.7789) followed by spring (0.41; 95% CI: 0.4082-0.4179), autumn (0.41%; 95% CI: 0.4069-0.4165) and winter months (0.26%; 95% CI: 0.2614- 0.2667). The live mass (Kg) of birds (IRR=5.706; 95CI: 3.696- 8.738), the number of birds rejected at farm level (IRR= 3.66; 85% CI: 2.437- 5.596), summer season (IRR= 1.873; 95% CI: 1.552- 2.60) and years (IRR=1.742; 95% CI: 1.486- 2.042) were significant predictors of DOA counts. The percentage of birds that were DOA in this study was low and decreased over the study period. The potential predictors of DOA counts identified in this study can be useful in guiding abattoirs and poultry farmers in managing broilers on farms, during catching, transportation and while in the lairage so as to minimize the DOA counts. Given the limited nature of this study in that it involved only one abattoir, there is a need for larger studies involving more abattoirs and farms to confirm the findings reported in this study.

Keywords: Animal welfare, Seasons, Biosecurity, Poultry farms, Risk factors, poultry producers

Abstrak

Dooie-by-aankoms (DOA) by pluimvee-abattoirs is 'n belangrike probleem waarmee pluimveeprodusente en abattoirs te kampe het, en dit lei jaarliks tot verliese van miljarde rande. Die verskynsel van DOA's is egter nie breedvoerig in Suid-Afrika ondersoek nie. Die doel van hierdie studie was om die tendens te ondersoek in die verhoudings van DOA's en faktore wat verband hou met DOA-tellings onder hoenders wat by 'n kommersiële slagpale in die Mopani-distrik in Limpopo, Suid-Afrika, geslag is. In hierdie studie is sekondêre data van braaikuikens wat tussen Januarie 2014 en Desember 2016 by 'n abattoir geslag is, gebruik om die tydelike neiging van DOA-tellings en faktore wat verband hou met DOA-tellings te beoordeel. 'N Negatiewe binomiale model was geskik vir die data om die verband tussen voorspellingsveranderlikes (d.w.s. jare, seisoene, biosekuriteit, kapasiteit, afstand afgelê, gemiddelde massa van voëls en plaasverwerping) en die uitkomsveranderlike (DOA-tellings) te ondersoek. Die persentasie DOA-tellings wat gedurende die studietydperk aangeteken is, was 0,48%. Die hoogste persentasie DOA's is waargeneem gedurende die somermaande (0,77%; 95% KI: 0,7695 - 0,7789) gevolg deur die lente (0,41; 95% KI: 0,4082-0,4179), herfs (0,41%; 95% KI: 0,4069-0,4165) en wintermaande (0,26%; 95% BI: 0,2614- 0,2667). Die lewende massa (Kg) van voëls (IRR = 5,706; 95CI: 3,696- 8,738), die aantal voëls wat op plaasvlak afgekeur is (IRR = 3,66; 85% BI: 2,437 - 5,596), somerseisoen (IRR = 1,873; 95 % GI: 1,552-2,60) en jare (IRR = 1,742; 95% GI: 1,486-2,042) was beduidende voorspellers van DOA-tellings. Die persentasie voëls wat DOA was in hierdie studie was laag, maar het gedurende die studietydperk afgeneem. Die potensiële voorspellers van DOA-tellings wat in hierdie studie geïdentifiseer is, kan nuttig wees om slagplase en pluimveeboere te begelei in die bestuur van braaikuikens op plase, tydens die vang, vervoer en in die laer om sodoende die DOA-tellings te verminder. Gegewe die beperkte aard van hierdie studie deurdat dit slegs een slagplaas behels, is daar 'n behoefte aan groter studies wat meer slagplase en plase betrek om die bevindinge wat in hierdie studie gerapporteer is, te bevestig.

Sleutelwoorde: Dood by aankoms, Dierewelsyn, Braaikuiken, Seisoene, Voorspellers, Bioveiligheid

Abstract

Ukufika-ekufikeni (i-DOA) kwizilarha zeenkukhu yingxaki ebalulekileyo abajongana nayo abavelisi beenkukhu kunye nezilarha zokuxhela kwaye ibangela ilahleko yeebhiliyoni zeerandi ngonyaka. Nangona kunjalo, imeko ye-DOAs khange iphandwe ngokubanzi eMzantsi Afrika. Injongo yolu phononongo yayikukuphanda imeko kumlinganiso we-DOAs kunye nezinto ezinxulumene nokubalwa kwe-DOA phakathi kweenkukhu ezixheliweyo kwindawo yokuxhela kurhwebo kwisithili seMopani eLimpopo, eMzantsi Afrika. Kolu phononongo, idatha yesibini yeenkuku ezixheliweyo kwindawo yokuxhela phakathi kukaJanuwari 2014 noDisemba 2016 yayisetyenziselwa ukuvavanya imeko yexeshana yokubalwa kwe-DOA kunye nezinto ezinxulumene nokubalwa kwe-DOA. Imodeli engalunganga yokulinganisa ibifanele idatha yokuphanda unxibelelwano phakathi kwezinto ezixeliweyo (okt, iminyaka, amaxesha, ukhuseleko, amandla, umgama ohanjiweyo, ubunzima beentaka kunye nefama eyaliwe) kunye nesiphumo esiguqukayo (ukubalwa kwe-DOA). Umyinge wezibalo ze-DOA ezirekhodwe ngexesha lokufunda yayiyi-0.48%. Elona nani liphezulu le-DOAs laqwalaselwa ngeenyanga zehlobo (0.77%; 95% CI: 0.7695 - 0.7789) kulandelwa intwasahlobo (0.41; 95% CI: 0.4082-0.4179), ekwindla (0.41%; 95% CI: 0.4069-0.4165) kunye neenyanga zasebusika (0.26%; 95% CI: 0.2614- 0.2667). Ubunzima obuphilayo (Kg) beentaka (IRR = 5.706; 95CI: 3.696-8.738), inani leentaka ezaliwe kwinqanaba lefama (IRR = 3.66; 85% CI: 2.437- 5.596), ixesha lehlobo (IRR = 1.873; 95 % CI: 1.552- 2.60) kunye neminyaka (IRR = 1.742; 95% CI: 1.486- 2.042) babengabalulekanga ababalulekileyo be-DOA. Ipesenti yeentaka ezaziyi-DOA kolu phando yayisezantsi kodwa yehla ngexesha lokufunda. Uqikelelo olunokubakho lobalo lwe-DOA oluchongiweyo kolu phando lunokuba luncedo ekukhokeleni izilarha kunye neefama zeenkukhu ekulawuleni iinkuku zenyama kwiifama, ngexesha lokuloba, ukuthuthwa naxa kuselwandle ukuze kuncitshiswe ukubalwa kwe-DOA. Ngenxa yokunqongophala kolu phando kuba luchaphazela isilarha esinye kuphela, kukho imfuneko yezifundo ezikhulu ezibandakanya izilarha kunye neefama ezininzi ukuqinisekisa iziphumo ezixeliweyo kolu phando.

Amagama aphambili: Ukufika ekufikeni, iNtlalontle yezilwanyana, i-Broiler, iiXesha, Abaqikeleli, Ukhuseleko

Sekhetho

Lefu la ho fihla (DOA) matlhabelong a likhoho ke bothata bo boholo bo tobaneng le bahlahisi ba likhoho le lits'oants'o mme bo baka tahlehelo ea libilione tsa liranta selemo se seng le se seng. Leha ho le joalo, ts'ebetso ea li-DOA ha e so fuputsoe haholo Afrika Boroa. Morero oa phuputso ena e ne e le ho fuputsa mokhoa oa boholo ba li-DOA le lintlha tse amanang le palo ea DOA har'a likhoho tse hlabiloeng setsing sa khoebo seterekeng sa Mopani ho la Limpopo, Afrika Boroa. Phuputsong ena, lintlha tsa bobeli tsa li-broiler tse hlabiloeng setlhabelong pakeng tsa Pherekhong 2014 le Tshitwe 2016 li sebelisitsoe ho lekola maemo a nakoana a lipalo tsa DOA le lintlha tse amanang le lipalo tsa DOA. Moetso o mobe o ne o lekana le tlhaiso-leseling ho fuputsa kamano pakeng tsa mefuta-futa ea likhakanyo (ke hore, lilemo, linako tsa selemo, ts'ireletseho, matla, maeto a tsamaeang, boholo ba linonyana le polasi e lahliloeng) le sephetho se fapaneng (palo ea DOA). Palo ea lipalo tsa DOA tse tlalehiloeng nakong ea boithuto e ne e le 0.48%. Karolo e phahameng ka ho fetisisa ea li-DOA e hlokometsoe likhoeling tsa lehlabula (0.77%; 95% CI: 0.7695 - 0.7789) e lateloa ke selemo (0.41; 95% CI: 0.4082-0.4179), hoetla (0.41%; 95% CI: 0.4069-0.4165) le likhoeli tsa mariha (0.26%; 95% CI: 0.2614-0.2667). Boima ba linonyana (Kg) ba linonyana (IRR = 5.706; 95CI: 3.696- 8.738), palo ea linonyana tse lahliloeng maemong a polasi (IRR = 3.66; 85% CI: 2.437- 5.596), sehla sa lehlabula (IRR = 1.873; 95 % CI: 1.552- 2.60) le lilemo (IRR = 1.742; 95% CI: 1.486-2.042) e ne e le likhakanyo tsa bohlokoa tsa lipalo tsa DOA. Peresente ea linonyana tse neng li le DOA phuputsong ena e ne e le tlase empa ea fokotseha nakong ea boithuto. Likhakanyo tse ka bang teng tsa lipalo tsa DOA tse fumanoeng phuputsong ena li ka ba molemo ho tataiseng lihoai tsa likonyana le likhoho ho laola likhoho tsa likhoho mapolasing, nakong ea ho ts'oasa, lipalangoang le ha ba le kahara lailage ho fokotsa palo ea DOA. Ka lebaka la sebopeho se lekanyelitsoeng sa phuputso ena ka hore e ne e ama setlhabelo se le seng feela, ho na le tlhoko ea lithuto tse kholo ho feta tse amang masaka le mapolasi a mangata ho netefatsa liphuputso tse tlalehiloeng phuputsong ena.

Mantsoe a bohlokoa: Lefu la ho fihla, Tlhokomelo ea liphoofolo, Broiler, Linako tsa selemo, Linohe, Ts'ireletso

Chapter 1: Introduction

1.1 Background

Dead on arrival (DOA) is defined as birds that are found dead on arrival at the abattoir (Eatwell, 2003; Ritz *et al*., 2005). For many years, DOA at poultry abattoirs has been a significant problem for poultry farms and abattoirs leading to losses of billions of rands to the industry (Ritz, *et al.*, 2005; Bolton, 2015). Studies done in England (Gregory and Austin, 1992), Britain (Warriss *et al*., 1992), Brazil (Nijdam *et al*., 2005), Canada (Silva *et al*., 2011) and Norway (Schwartzkopf-Genswein *et al*., 2012; Vecerek *et al*., 2017) show that high percentages of DOA among broilers can result in a loss of millions of dollars per year in revenue.

According to Kittelsen *et al*. (2017), the number of chickens slaughtered has increased drastically over the past years from 20 billion birds in 2000 to 59.8 billion birds in 2012 globally. This is because; poultry production plays a substantial role in the economy of many countries. For example, in South Africa the poultry industry contributes 16% to the gross domestic product (GDP) and 50% to the total poultry production of the African continent (Bolton, 2015).

Conditions during the pre-slaughter phase such as feed and water withdrawal, handling, temperature changes, and congestion have been shown to increase the incidence of DOA (Jacobs *et al.*, 2017; Kittelsen, *et al.*, 2017) . The physiological status of the bird including heart conditions, and infectious conditions have also been shown to influence the incidence of DOA in broilers (Druyan, 2012; Julian, 1993). Available evidence suggests that the tropical and high rainfall region conditions in South Africa can result in significant loses prior to chicken slaughter (Guerrero-legarreta, Roldan-santiago and Mota-rojas, 2016). Studies conducted in other countries demonstrated that the occurrence of DOA is a key indicator of animal welfare (Jacobs *et al.*, 2017). The effect of atmospheric temperatures on chicken through the pre-slaughter phase in subtropical climate has been shown to significantly impact on the occurrence of DOA (Vieira *et al*., 2015).

Studies done in England (Gregory and Austin, 1992), Britain (Warriss *et al.*, 1992), Brazil (Nijdam *et al.*, 2005), Canada (Silva *et al.*, 2011) and Norway (Schwartzkopf-Genswein *et al.*, 2012) suggest that the proportions of broilers recorded as DOA at abattoirs ranges between 0.05% and 0.57%, and may represent a loss of millions of birds per year. In view of these, there is a need for good production practice and high welfare standards when moving chicken from the farm to the abattoir in order to reduce the rate of DOA (FAWC, 2013). However, there is no evidence of studies that have assessed the prevalence and factors associated with DOA counts at poultry abattoirs in South Africa.

This study investigated the trend of the occurrence of DOAs and factors associated with DOA among chickens slaughtered at a selected abattoir in Limpopo, South Africa. The information generated from this study can be used to develop guidelines for management of chickens to reduce the incidences of DOA and the associated economic impact.

1.2 Research problem

There are enough economic reasons to justify taking care of birds during production and shipment to the slaughter plant (FAWC, 2013). However, there is no evidence of published studies that have assessed the factors associated with DOAs in the South African poultry industry. Therefore, there is a gap in the body of knowledge on the phenomenon of DOA with reference to the slaughter plants in South Africa. It is hoped that information generated from this study will be used to reduce losses the poultry industry suffers by helping identify factors that are significantly associated with DOA.

1.3 Aim, research questions and objectives

1.3.1 Aim

The aim of this study was to investigate the prevalence of DOA and factors associated with DOA among chickens slaughtered at a selected abattoir in Limpopo Province, South Africa.

1.3.2 Research Questions

The study was based on the following research questions:

i. What is the proportion of DOA among broilers slaughtered at the selected abattoir between 2014 and 2016?
ii. Was there a change in the proportion of DOAs observed at the abattoir under study between 2014 and 2016?
iii. What factors were significantly associated with DOA counts among chickens slaughtered at the abattoir under study?

1.3.3 Objectives

To answer the above research questions, the research was guided by the following objectives:

i. To describe the prevalence of DOA among chickens slaughtered at the selected abattoir.

ii. To establish the factors that predict DOA among broilers slaughtered at the abattoir under study.

1.4 Anticipated benefits of study

i. The results of this study can be used to help guide improvements in the standard of broiler chicken production in the abattoir under study.

ii. Information generated from this study can be used to reduce economic loses the poultry industry suffers by helping identify factors that are significantly associated with DOA.

1.5 Ethical and legal considerations

i. To conform to the requirements of UNISA ethics research committee, ethics approval was secured before research commenced (**Appendix 1**).

ii. Authority to use the data for this research was secured from the owners of the data before the study commenced (**Appendix 2**).

iii. The name of the abattoir where the research was conducted was kept anonymous and any publications arising out this research had to be presented to the abattoir management before publication.

iv. Data was kept confidential and only the researcher and other authorised persons had access to the data.

v. After the study had been finalised, the data was kept in a password protected computer.

vi. Since no live animals were used in this study, there was no need to request for clearance from the animal ethics committee.

vii. Furthermore, no interviews were conducted and so there was no need for consent forms.

1.6 Limitations of the study

This was a retrospective study based on secondary data. Therefore, the study was limited to variables that were available in the database. Hence, it was not possible to assess the role of other factors, such as disease status on the farms and farm management on the number of DOAs reported. Secondly, the study was limited to one abattoir; and as a result, the findings of this study cannot be generalised to all the abattoirs in the country. Despite these limitations, the findings of this study contribute to the body of knowledge on the factors that are significant for DOAs and, therefore, can be used by farmers and abattoir owners to minimise losses attributed to DOAs.

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Chapter 2: Literature Review

2.1. Background

2.1.1. Poultry production in South Africa

Poultry production is reportedly the largest division of the agricultural sector in South Africa (Machethe, 2016). In 2018, the poultry industry made a major contribution (48.5%) to the total gross value of agricultural production in South Africa (AgriSETA, 2020). Approximately 3.6 million tons of poultry and other meat products are consumed by South Africans annually, with poultry meat representing 60% of the total meat consumed (DAFF, 2018; AgriSETA, 2020). Moreover, the consumption of animal protein in South Africa has increased by over 90% from 38kg per person in 2008 to 40kg in 2017 with broiler meat being the most consumed (Bolton, 2015; DAFF, 2018).

Poultry production also contributes significantly to food security by acting as a strategic means of addressing animal protein intake deficiency in human diet (Davids, 2013). Results of a study conducted in 2018 show that broiler meat remains the most affordable source of protein when compared to other animal proteins in South Africa (DAFF, 2018). It is said to be the fastest growing industry in the South Africa (Bolton, 2015). However, the country still depends on imports to satisfy the demand. Broiler meat produced in the country is consumed locally and also exported to the Southern African Development Community (SADC) countries such as Namibia, Botswana, Lesotho, Zimbabwe, Mozambique, etc. from over 1700 entities (DAFF, 2018; Fairplay, 2019).

2.1.2. Commercial broiler farmers and smallholders

To satisfy the market demand for poultry meat in South Africa, broiler chickens are produced by both commercial and smallholder poultry farmers (DAFF, 2013a). According to AgriSETA (2020) and Machethe (2016), the number of smallholder broiler farmers is significantly higher compared to the commercial farmers, and represents over 85% of the total number of broiler farmers in South Africa. That notwithstanding, commercial farmers produce over 1700 million broilers yearly (AgriSETA 2020).

The smallholder broiler farmers offer opportunities for the rural producers to participate in the market to ensure a sustainable livelihood (SAPA, 2018a). Smallholder broiler farmers are normally family operations and trade their produce through live broiler meat market which generally depends on small vendors for distribution to consumers (DAFF, 2013b). AgriSETA (2020) defines commercial broiler producers as large corporates that produce broiler chickens on a huge scale and have a regulated supply chain from production to growing, slaughtering and packaging.

2.1.3. The distribution of poultry farms in South Africa

Broiler chickens are farmed throughout South Africa with North West Province being the major producer and represents approximately 23% of the total production (Figure 2.1). Meanwhile, Limpopo Province ranks last and represents 2% of the poultry production in the country (DAFF, 2018; SAPA, 2018a; AgriSETA, 2020).

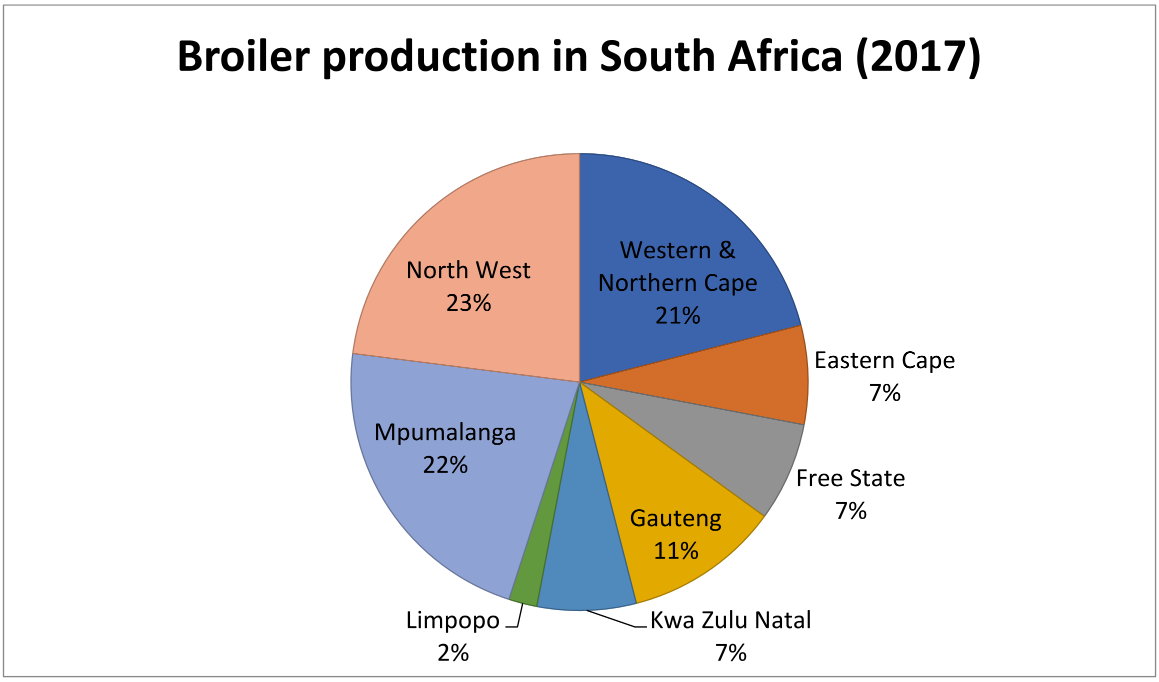

Figure 2.1.: The distribution of broiler production by province in South Africa for the year 2017 (Source: AgriSETA, 2020).

2.1.4. Operational plan of poultry production in South Africa

Figure 2.2 below summarizes the operation plan for broiler production. The initial stage of broiler chicken supply is characterized by the primary breeder flock (Davids, 2013). Broiler producers in South Africa mostly use genetics from different breeds such as Arbor Acres, Cobb, Ross etc. (Hayes, 2013). According to Goga and Bosiu (2019), Ross and Cobb broiler breeders are imported into South Africa at grandparent level. From the grandparent flocks, day-old stock are produced at parent rearing farms, breeder farm houses and hatcheries followed by distribution to contract growers. Poultry producers provide feed for rapid growth that enable broilers to attain an average of 1.85kg per bird prior to distribution to processing abattoirs that supply poultry meat to consumers (Hayes, 2013).

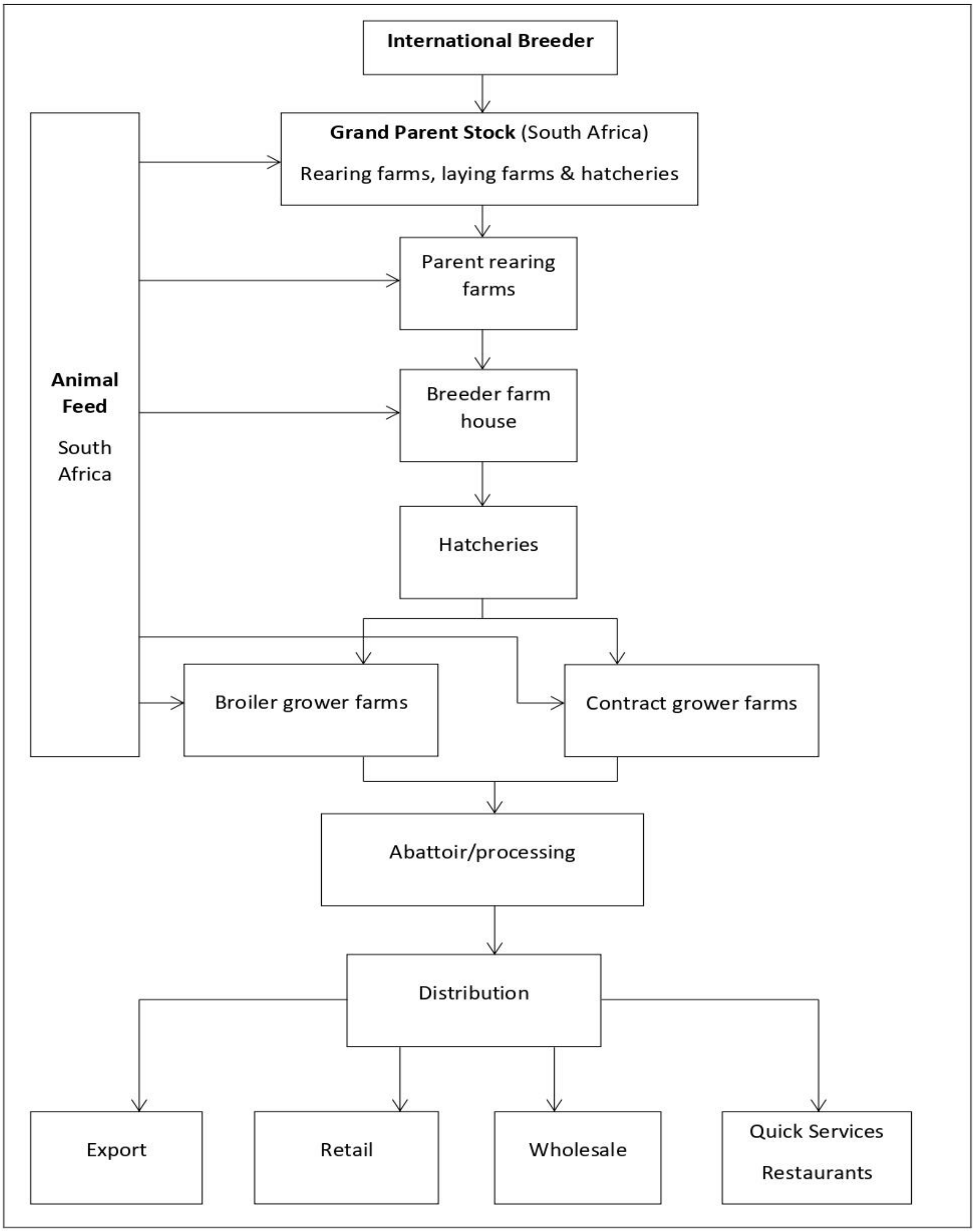

Figure 2.2.: The production process of broilers from farms to the processing plants (Source: South African Poultry Association, 2013).

Broiler farming requires very strict compliance to regulations by national and international bodies (SAPA, 2018b). Prior to receiving of every new batch of day-old chicks, all surfaces and equipment in the building are cleaned and disinfected and left empty for a minimum period of seven days before restocking (Pocock and Joubert, 2017). According to Davids (2013), this process prevents the carry-over of infections between flocks.

Strict management of temperature at around 15-33˚C, quality of water, lighting (approximately 20 lux) and ventilation (Carbon dioxide <3000ppm) are very significant and require inspections at least twice a day (Davids, 2013). This is usually performed by trained individuals as a control measure for diseases and mortality.

According to guidelines described by SAPA (2012), where husbandry deficiencies are detected corrective action needs to be taken in accordance with the welfare of the birds. Additionally, during inspections attention should be given to the comfort of birds and proper operation of equipment. Injured and sick birds have to be attended to, and where necessary disposed of humanely (DAFF, 2012).

To ensure that nutritional requirements are fulfilled for vitality and good health, the birds are fed with a diet that contains suitable nutrients (protein, minerals, vitamins etc.) and provided with enough potable water daily (DAFF, 2012; Ralivhesa *et al.*, 2013; Pocock and Joubert, 2017).

To prevent infectious diseases on farms, a preventative program is employed that involves vaccinations and biosecurity measures (SAPA, 2018b). Live birds with clinical signs of disease or batches with high mortality rates are submitted to a veterinarian for diagnosis followed by endorsements for treatment and rejection of birds unfit for catching (SAPA, 2012b; Davids, 2013; Guerrero-legarreta, Roldan-santiago and Mota-rojas, 2016; Kittelsen, Granquist, *et al.*, 2017).

Several hours (approximately 8 hours) prior to catching and loading, the provision of feed and water is stopped. This helps to minimize and/or prevent faecal contamination at the abattoir (Jacobs, 2016). According to Hayes (2013), birds should be handled by both legs and full support of the body during catching. The same author recommends that the maximum number of birds carried by one catcher at one time should not exceed four. Birds should be loaded into hygienic crates with a lid and transported in a clean roadworthy vehicle (SAPA, 2018b). Additionally, birds should not be in transit for over 24 hours and the driver transporting birds to the processing plant should be trained in transporting livestock (SAPA, 2012b, 2018b).

2.1.4. Operations at abattoirs

In 2012, DAFF (2012) estimated that the number of formal broiler abattoirs in South Africa was approximately 260, slaughtering over 4.7 million birds weekly. The slaughter process in poultry plants entails a number of stages that are guided by the Poultry Regulation

R153 of 2006 (Pocock and Joubert, 2017). In high-throughput abattoirs (slaughter over 2000 birds per day), processes are carried out by automated machinery. Whereas in low-throughput abattoirs (slaughter a maximum of 2 000 birds per day), most operations are carried out manually (Davids, 2013; Pocock and Joubert, 2017).

The different slaughter steps are presented in Figure 2.3, and include: the pre-slaughter phase, inspections, washing, portioning, packaging, chilling and freezing (Jacobs, 2016). Upon arrival at the abattoir, birds are held in the lairage, and ante mortem inspections are carried out whereby birds are inspected for injuries, sickness and moribund (Bergh, 2007). It is during this stage that DOA birds are identified and condemned, whilst injured birds suitable for processing are slaughtered immediately (Bergh, 2007; Löhren, 2012; Arbo, 2018). After ante mortem inspection, crates with birds are put on a conveyor belt and shackled manually followed by stunning in an electrical water bath (Jacobs, 2016). This is followed by slaughtering of birds either manually or mechanically depending on the method in place.

The slaughter process includes three mandatory carcass and meat inspection points: immediately after de-feathering when birds are still unopened, followed by the stage directly after evisceration when the organs are still attached to the carcass. The last inspection is conducted on mechanical lines (Bergh, 2007).

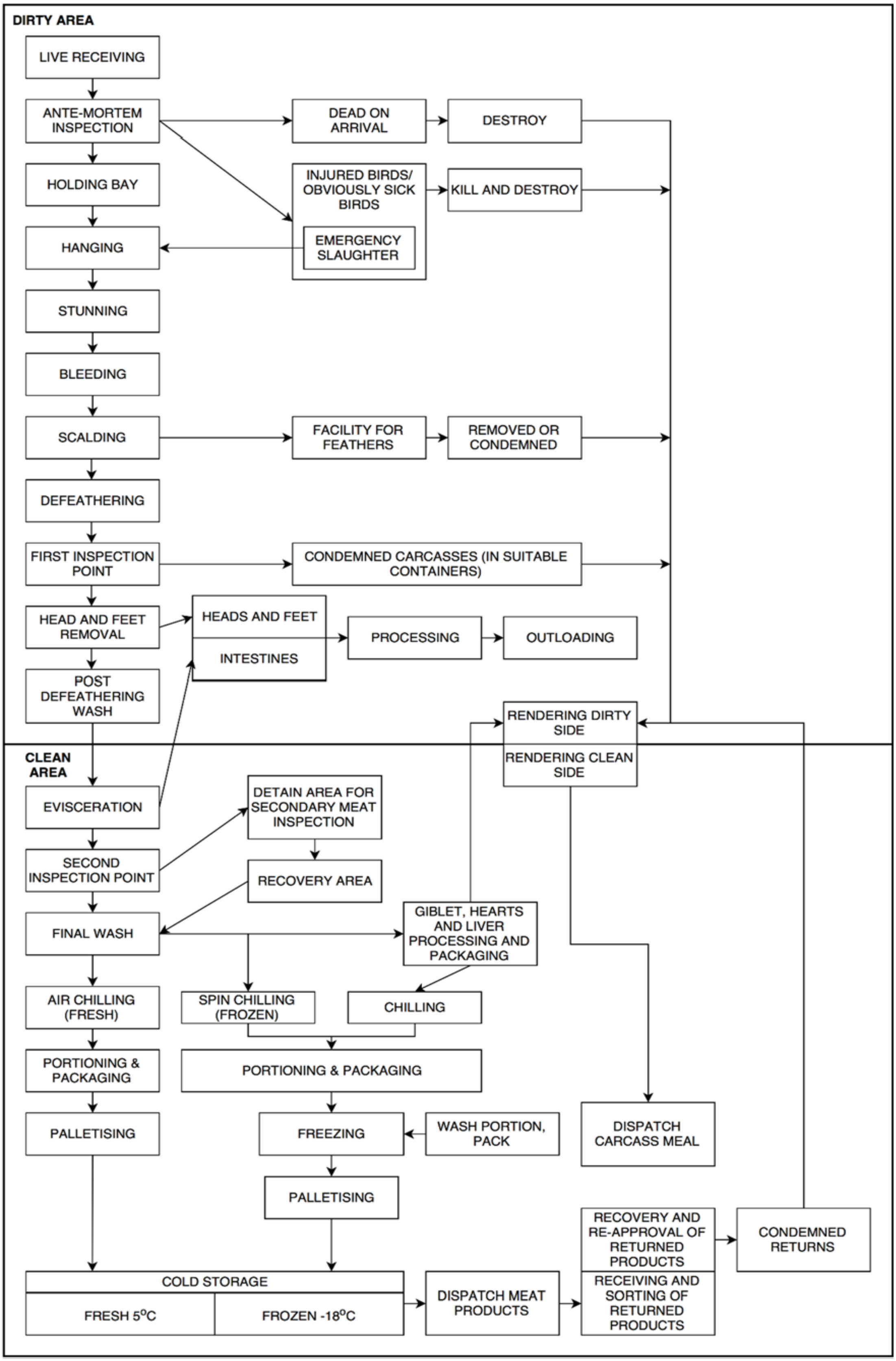

Figure 2.3: Common production process of broiler chickens at processing plants (abattoirs) (Source: Bergh, 2007).

2.2. Dead on arrival broiler chickens

2.2.1. Occurrence of DOA among broiler chickens

Stressful conditions during loading, transportation as well as presence of disease on the farm contribute to the occurrence of DOA observed at the abattoirs (Mitchell and Kettlewell, 1994; Petracci, 2006). Stressors that have been associated with DOAs include feed and water withdrawal, handling, temperature changes, noise, vibration, acceleration and congestion during the pre-slaughter stage (Kittelsen *et al*., 2017). Conditions in the farm houses, fast growth rates, crowding, and high vitality amounts can lead to oxygen shortage in broiler chicken, triggering hypertrophy of the heart ventricle and then congestive heart failure (Julian, 1993). In addition, laryngitis and tracheitis in broilers are common and are also known to lead to DOA (Druyan, 2012). Pre-slaughter stress accounts for a large percentage of losses before the arrival of broiler chickens at the abattoir (Ritz *et al.*, 2005).

The percentage of DOA differs significantly among studies, and on average ranges from 0.13 to 0.46% (Table 2.1). According to Jacobs (2016), the differences in the prevalence of DOAs could be due to the climatic conditions in the study area, the health status of birds or pre-slaughter practices between farms and abattoirs.

Table 2.1: The overview of studies showing the percentage of mean DOA, sample size, potential factors in various countries.

Country	Dead on arrival (%)	Sample size (n)	Potential factors	Reference
Spain	0.187	9 188 shipments	Large birds' mass, transport distance, the practice of thinning, lairage time and high temperatures.	Villarroel *et al.* (2018)
Czech Republic	0.37	692 738 409 broilers	Winter (colder) months and travel distances exceeding 300 km.	Vecerek *et al.* (2016)
	0.25	Unknown	Longer transport distances	Vecerek *et al.* (2006)
Belgium	0.30	18 000 broilers	Lesions on thighs and vent, plumage hygiene, panting, body temperature and recumbent birds.	Jacobs (2016)
Netherlands	0.46	1 907 flocks	Stocking density, transport time and lairage time.	Nijdam (2006)
England	0.13	59 171 843 broilers	Summer months	Warriss *et al.* (2005)

2.2.2. Economic impact of dead-on-arrival broilers

In a study by Ritz, *et al.* (2005), it was observed that the financial losses associated with DOA broilers and injury could be massive. The same authors observed that an abattoir that processes 1.25 million broiler chickens per week can incur a loss of up to $325 000 per year, which may amount to millions in South African Rands. Moreover, the estimate of $325 000 per year was based on the number of birds processed per year. However, if a DOA rate of 0.4% (260 000 DOA broilers per year) and a unit price of $0.25 (of which an average broiler chicken weight is 5lb) are factored into the calculation, the losses could be much more.

2.3. Factors associated with the occurrence of DOA broilers

2.3.1 Climatic factors

In the study of pre-slaughter mortality of broilers, Vieira *et al.* (2011) explained that high ambient temperatures, large moisture dissimilarities and low ventilation result in significant losses of broilers during the pre-slaughter phase. In another study, the same authors suggested that heat stress caused by high atmospheric temperatures during the pre-slaughter phase accounted for most of DOA before the chickens arrive at the abattoir (Vieira *et al*., 2015).

Additionally, studies of DOA in hot environments during hauling, estimated that 40% of DOA were linked to heat or cold stress and also observed that the majority of deaths tended to occur during loading and in the lairage (Ritz *et al.*, 2005). Warriss *et al*. (2005) also identified associations between mortality during transportation and maximum ambient temperature. In the same study, it was reported that the highest proportions of deaths occurred in summer when it was too hot. According to Hunter (1998), an increase of 10°C in modules can results in hyperthermia in broiler chickens particularly when ventilation in the vehicle is too low. Thereafter, severe complications such as muscle haemorrhages may follow, resulting in death (Nijdam *et al.*, 2006).

2.3.2 Feed withdrawal

Feed and water are usually withdrawn for some hours before catching of broilers. The purpose of this is to reduce the risk of carcass contamination during slaughter (Jacobs, 2016). It is recommended that water and food should be withdrawn at least eight to ten hours (8 – 10 hours) before slaughter. However, in practice, this period is usually longer (Nijdam, 2006).

Studies conducted in Netherlands show that water and feed are withdrawn 5 hours prior to catching whereas one vehicle takes approximately 55 minutes to load 6 500 chickens. Therefore, for a house with 20 000 chickens, it could take up to 3 hours to complete the catching, while a house of with 60 000 chickens could take up to 9 hours. Additionally, transference from farm to the abattoir could take up to 134 to 210 minutes, and when the birds get to the abattoir, the broiler chickens are held in the lairage for an average of 150 to 955 minutes (Nijdam *et al.*, 2004). Therefore, the entire feed and water withdrawal period takes approximately 12 hours and 45 minutes. Nevertheless, in a worst-case scenario, the total time of feed withdrawal can be 33 hours and 30 minutes.

Nijdam (2006) reported that feed and water withdrawal causes body weight loss between 0.22% - 0.56% per hour. Nijdam (2006) is also of the view that this process affects numerous metabolic processes resulting in a catabolic state which results in an increase in non-esterified fatty acids and a decrease in circulating triiodothyronine. According to Jacobs (2016) the low levels of triiodothyronine in chickens is a sign of a very strong stress response which may affect the quality of meat or cause sudden death.

2.3.3 Catching broilers at farm level

2.3.3.1 Mechanical catching

Mechanical catching equipment is gradually being used in the broiler chicken industry. This is mainly to curb high labour costs. In addition, according to Grandin (2017) the replacement of manual catching with mechanical catching results in less stress and injury to broilers. During mechanical catching, chickens are gathered with soft rubber-fingers on a conveyer belt into the carriage modules crates. This is also supported by Nijdam (2006) who is of the view that mechanised catching is less stressful to broilers when compared to manual catching. This is because it handles the broiler chickens gently and also shortens the physical contact with human.

In contrast, Musilová *et al.* (2013) is of the opinion that broilers caught by a machine were more fearful than those that were handled gently by hands. However, the same authors indicated that short-term stress linked with the mechanical catching of broiler chickens may be lowered by using well-designed equipment. Knierim *et al.* (2003) and Ekstrand (1998) indicated that among others, the disadvantages of mechanical catching include the operators of the mechanical harvesters harvesting sick or unfit birds that might not survive the pre-slaughter process and as a result end up as DOA.

Although in general mechanical catching is associated with less stress and injury among the birds, some studies have reported higher rates of DOA among broilers caught with mechanical catching (Nijdam *et al*., 2005). This has been attributed to the presence of birds that were sick in mechanically loaded modules. In a study by Nijdam *et al*. (2004) that investigated meat quality in broilers that were caught mechanically and manually, it was observed that mechanical catching was associated with higher proportions of broilers that were recorded as DOA during the pre-slaughter phase. As a result, the use of mechanical catching equipment necessitates both training and familiarity together with proper animal welfare (Delezie *et al.*, 2006).

2.3.3.2 Manual Catching

Incorrect handling and transportation to the processing plants has been associated with a high proportion of DOA broilers (Knowles and Broom, 1990). In a study by Nijdam *et al.* (2005) that investigated biochemical factors associated with the quality of meat such as corticosterone, lactate and glucose in broilers, it was found that the plasma levels of these compounds was higher in manually caught birds compared to those that were caught using mechanical catching. Furthermore, Mitchell and Kettlewell (1994) found that manual catching and tightly packing of broiler chickens into crates prior to transportation to the abattoir is a major cause of stress and trauma to the chickens.

During manual catching, broilers are caught either by both legs, or one leg and a wing, three or four broilers per hand, prior to loading into the modules (Kettlewell and Turner, 1985). On a normal workday, a catcher will lift approximately five tons of broilers at a rate of 1000 to 1500 chickens per hour. This is a demanding job, and it may not be easy for the catchers to sustain focus throughout the day (Nijdam *et al.*, 2004). Rough handling may cause fear, resulting in physical injuries and death. This is attributed to broilers not being familiar with being touched by humans, and so when they are touched, they experience fright and trauma (HSUS, 2009).

2.3.4 Transportation

Broilers are normally transported in piled crates with inadequate ventilation which may result in a reduced air flow. This results in confined humid conditions in crates, which reduces the effectiveness of breathing as the ventilation of stacked crates is poor, and because chickens cannot thermo regulate under high environmental temperatures (Warriss, *et al.*, 2005). In the study by Mitchell & Kettlewell (1994), it was found that the temperature increases drastically in moving trucks creating a thermal core in crates carrying chickens.

The microclimate in the vehicle has also been recognised as a major cause of DOA among broilers in transit (Schwartzkopf-Genswein *et al.*, 2012). It has also been revealed that DOA in broilers is influenced by the time and distance from farm to the abattoir (Nijdam *et al.*, 2004; Oba *et al.*, 2009). During the investigation of DOA broilers in relation to the length of journey to processing plants, Warriss *et al.* (1992) indicated that the rate of DOA broiler chickens was 0.16% in trips that were 4 hours and less. Whereas for trips that were 4 hours and longer, rates of up to 0.28% were recorded.

Furthermore, in a study by Arikan *et al.* (2017), DOA percentages ranged from 0.29% in trips that took less than 2 hours to 0.46% for trips that took 10 hours and above. Mitchell and Kettlewell (1998) established that insufficient ventilation caused a dissimilar circulation of temperature and humidity in trucks and that the presence of a thermal core in trucks increased the risk of heat stress. Other stress factors for broiler chickens in transit include the following: vibration, sound, rough driving, distance and time of transportation, off-loading and time spent in the lairage at the abattoir (Fitzgerald, 2017; Fontana *et al*., 2017; Kannan *et al*., 1997; Knowles & Broom, 1990; Mitchell & Kettlewell, 1998; Voslarova *et al*., 2007).

2.3.5 Lairage time

Lairage time refers to the period between when the vehicle carrying the broiler chickens arrives in the holding area and when crates are off-loaded in the off-loading/receiving bay (Edy Susanto, 2019). During this time, broilers are exposed to various stresses while being held in modules on immobile vehicles at the abattoir before shackling (hanging on the slaughter line). Moreover, the time that is spent in the lairage may be equal to the time travelled from the farm to the processing plant/abattoir (Warriss *et al.*, 1992).

While in the lairage, due to the poor aeration of the modules, a high thermal load could be imposed on the chickens. This could be worsened by exterior climatic circumstances, the temperature in the lairage, the location and the set-up of modules in the building (Warriss, *et al.*, 2005).

According to Vieira *et al.* (2015) holding broiler chickens in a temperature-controlled areas such as the lairage for an appropriate time allows for circulation of cooled air inside crates before slaughter. This has the potential to decrease thermal stress among broilers after transportation. However, when the body temperature of chickens rises, the liver glycogen supplies become worn-out, resulting in substantial phases of negative energy balance. Therefore, lairage times even under controlled environments, have the potential to impact mortality rates differently depending on the season. For example, the rate of DOA broilers during pre-slaughter phase may be high during summer months as compared to winter months even if the lairage time is similar (Hunter, 1998; Nijdam *et al.*, 2004). In view of this, the same researchers recommended short holding times in the lairage to prevent death of broilers that are metabolically weak. Contradictorily, Petracci *et al.* (2006) reported that there was no substantial effect of lairage time on the rate of DOA, but rather suggested a controlled feed withdrawal time to reduce the number of DOA.

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Chapter 3: Research Methodology

3.1 Study area

The study was conducted at a commercial poultry abattoir in the Mopani district, Limpopo province, located North East of South Africa (Figure 3.1). The district consists of five municipalities (i.e.; Greater Tzaneen, Ba-Phalaborwa, Greater Maruleng, Greater Letaba, and Giyani Municipality). The population of Mopani district consists mostly of VaTsonga, BaLobedu, and Afrikaners. The area has a population of approximately 1 092 507 people living within the area of 20 011 km² (EcoAfrica, 2016).

Figure 3.1: Map of the Mopani district showing the five municipalities that make up the district (Source: Yes Media, 2012).

Mopani district is well known for production of poultry, fruits and vegetables, livestock, and timber. It is also one of the major producers of tea, mangoes, nuts, paw-paws and bananas consumed nationally and globally. Therefore, the agricultural sector of Mopani district is one of the biggest contributors to employment and economic strength in South Africa (Machethe, 2016).

3.2 Climate in the Mopani district

The Mopani district as a region is well known for its warm temperatures that range from approximately 10 to 40°C, rugged mountains on its western edge and surge waterfalls (COGTA, 2020). The climate diverges from sub-tropical to tropical temperatures with a high humidity and receives rainfall throughout the year (DEDET, 2016). However, most of the rain (approximately 85%) is received during summer months (DEDET, 2016; COGTA, 2020).

Although variations in temperatures are observed over seasons, the eastern parts of the study area experience colder temperatures compared to the north-eastern regions (DEDET, 2016). The highest average temperatures (25 - 30°C) occur between November and February while the minimum average temperatures (7- 15°C) occur between May and August (Figure 3.1).

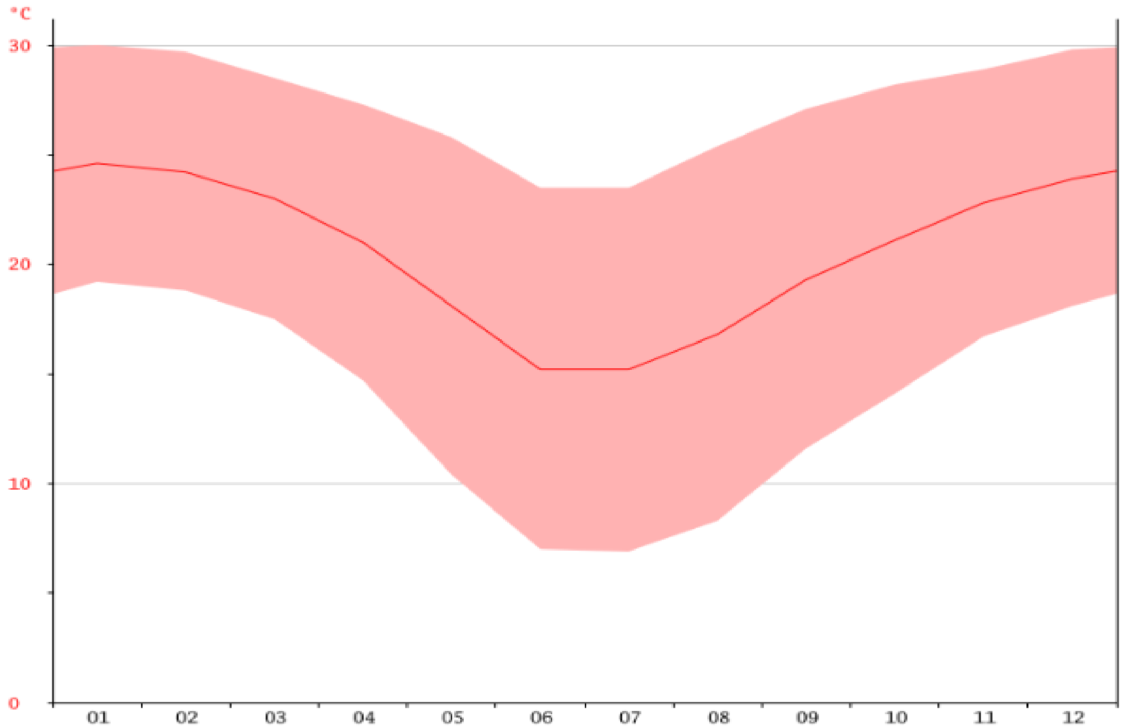

Figure 3.2: Graph showing the average annual temperatures in the Mopani District (Source: Climate Data Org, 2018).

3.3 Harvesting, transportation and processing of birds at the abattoir

The abattoir under study sourced birds from contracted farms around Mopani district. The farms that supplied the abattoir had to meet the following criteria to qualify to supply broilers to the abattoir: have houses with a minimum carrying capacity of 38 000 birds per house and implement strict animal welfare practices. These farms grew only hybrids such as: Cobb500, Ross308 and Arbo Acres.

Both male and female birds are harvested when they are 32 - 34 days old, with an average live body mass that ranges between 1.7 and 2.8kg. Prior to harvesting of the birds, feed is withdrawn, followed by inspection of the flocks. Birds with signs of emaciation, underweight (runts), septicaemia, ascites and dermatitis that are detected at this point are removed from the flock. The rest of the birds are then caught and loaded onto ventilated crates and transported to the abattoir using sixteen tonne trucks. Catching of birds is done manually by trained catchers.

On arrival at the abattoir, each load is weighed and transferred to the lairage where broilers in each crate are counted. This is the time when birds that dead-on-arrival (DOA) are identified and taken to the rendering plant for destruction. Meanwhile, birds that are suitable for slaughter are shackled onto the slaughter line, stunned and manually slaughtered. Bleeding is then followed by scalding, defeathering, evisceration and further processing such as brining, portioning and packing.

3.4 Data source and management

3.4.1 Source

Retrospective data from the abattoir that slaughters broiler chicken supplied by broiler farms (n=26) located in the Mopani district of South Africa was used for this study. The dataset covered the period from January 2014 to December 2016.

The following variables were extracted from the dataset stored in Anzio Lite-Smartech software (Rasmussen Softwares, USA, 2015): farms that supply the abattoir with broilers, the distance from farm of origin to the abattoir, mass of birds delivered daily, the number of birds rejected at the farm during harvesting, the total number (batch size) and total mass of birds delivered to the abattoir, the number and total mass of the DOA, number and total mass of birds slaughtered and the number of rejected carcasses after the inspection of carcasses at the processing plant.

3.4.2 Data management

All the data was entered and stored into a Microsoft Excel file (*Microsoft Corporation,* USA, 2013). The data was evaluated for missing values and any inconsistencies such as implausible values, and none were found. All the analysis was conducted using the Statistical Package for Social Science (SPSS version 24) (*IBM*, Chicago, 2018).

3.4.3 Data analysis

3.4.3.1 Descriptive statistics

The continuous variables such as the number of DOA, the quantity of birds (rejected, delivered, slaughtered and processed) and the distance travelled by birds from farms of origin to the abattoir, were tested for normality using the Shapiro-Wilk's W test and constructing the Q-Q plots (Appendix 3). None of the variables tested was normally distributed, therefore, the median and quantiles were computed. In addition, proportions of DOA birds and their 95% confidence intervals by month, year, season, and the farm of origin were calculated and presented as tables and graphs.

3.4.3.2 Inferential statistics

Since the outcome variable (DOA), was a count, a Poisson model was initially fit to the data to determine the explanatory variables (i.e., year, season, biosecurity, capacity, distance travelled, birds average mass and farm rejected) that were significantly associated with the outcome variable (Table 3.1). Poisson distribution assumes that the conditional variance is equal to the conditional mean (Bhaktha, 2018). However, assessment of the Goodness-of-fit of the Poisson model indicated that the variance was greater than the mean, suggesting that the data suffered from over-dispersion. In instances of over-dispersion, the results of the Poisson model may be inadequate, therefore, a Negative Binomial (NB2) Regression model was considered for this study (Pattiz, 2009). The batch size (daily quantity of birds delivered) was employed as the exposure/offset variable when fitting the model.

Univariate models were fit to the data to assess the relationship between DOA counts and individual predictor variables **(Appendix 5)**. All predictor variables that were significant at $p \leq 0.2$ were included into the multivariable model. A multivariable Negative Binomial Regression model using backward stepwise selection was then fit to the data to assess the relationship between predictor variables and the counts of DOA as the outcome. Variables resulting in >10% change in coefficients of other variables when removed from the model were retained in the model as potential confounders. Incidence Rate Ratio (IRR) and their corresponding 95% confidence intervals were computed for all variables included in the final model. A $p<0.05$ was considered significant in the parameter estimates results.

The Variance Inflation Factor (VIF) was computed to assess the presence of multicollinearity among variables in the final model, with a value of <10 suggesting no multicollinearity. Furthermore, based on the collinearity statistic (VIF=1.003) no significant collinearity was observed in the final model.

Table 3.1: Variables included in the model

	No	Variable Name	Definition	Type of variable (Code)
Dependent Variable		Count DOA	The number of birds that was recorded as Dead-on-Arrivals.	
Independent Variables	1	Seasons	Seasons of the year.	Categorical (1= Winter, 2=Spring, 3= Summer, 4= Automn)
	2	Birds Average Mass	Average mass of individual birds.	Continuous
	3	Quantity Delivered	The quantity of birds that were delivered at the abattoir.	Continuous
	4	Farm Rejects	Birds that were rejected at farm level, also known as Dead-on-Farm.	Continuous
	5	Distance travelled	The distance from farms to the abattoir of study.	Categorical (0= <20km, 1=>20km)
	6	Capacity	The number of birds that a house can hold at a time.	Categorical (0= 38 000, 1= 48 000)
	7	Biosecurity	Facilities that are designed to reduce/prevent birds from infections such as fence, sanitation shower at the entrance, etc.	Categorical (0= No biosecurity, 1=biosecurity present)
	8	Year	Years in the study period	Categorical (1= 2014, 2=2015, 3= 2016)

3.5 Model diagnosis

The likelihood ratio Chi-Square provides a test of comparison between the null model (empty model) to the model with predictors (Nayak and Hazra, 2011). The likelihood Ratio Chi-Square for the final model indicated that the model with variables explains the outcome better than the null model (p=0.001) (Appendix 4). The Akaike's Information Criterion was used to compare modules. Models with the lowest AIC were considered to be better models.

3.6 References

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Chapter 4: Results

4.1 Farm details

The profile of houses that supplied the abattoir with broilers is summarized in Table 4.1. Out of the 26 farms that supplied the abattoir with birds, most (69%, 18/26) had only one house and only one farm (4%; 1/26) had four houses. Two farms (8%; 2/26) had three houses, one farm (15%; 4/26) had four houses, and three farms (12%, 3/26) had six houses per farm. The majority of farms (69%; 18/26) had houses with a carrying capacity of 38 000 broilers per house. The rest (31%, 8/26) had a carrying a capacity of 48 000 per house.

Out of the farms that supplied the abattoir with chickens, 46% (n=12/26) had a fence and a sanitation shower by the gate as part of biosecurity to limit the introduction of diseases or entry of other animals onto the farm; whereas 54% (n=14/26) did not have biosecurity facilities. The median distance travelled by broilers from farms to the abattoir was 18 km (IQR:3- 23).

Table 4.1:The profile of farms that supplied the abattoir with broilers during the study period (2014-2016).

Variable	Level	Number of farms n (%)
Houses on farm	1 house per farm	18 (69.2)
	3 houses per farm	2 (7.7)
	4 houses per farm	1 (3.8)
	6 houses per farm	3 (11.5)
	7 houses per farm	2 (7.7)
Carrying capacity	Capacity per house	
	48,000 birds	8 (30.8)
	38,000 birds	18 (69.2)
Biosecurity	Presence of biosecurity	
	Biosecurity measures present	12 (46.2)
	Biosecurity measures absent	14 (53.8)

4.2 Broilers delivered, slaughtered and processed.

A median number of broilers delivered to the abattoir over the study period was 40 018 (Q1: 34 867 -Q3: 45 461) per day, and the median weight of broilers delivered over the same period was 1.73 kg (Q1: 1.64 – Q3: 1.82). The median number of birds rejected on the farms per day was 177 (Q1: 103- Q3: 291), while over the same period, the median number of broilers recorded as DOA was 104 (IQR: 51 - 209). Meanwhile, the median number of carcasses that were recorded as process rejects was 56 (Q1: 33- Q3: 93) per day (Table 4.2).

Table 4.2: Mean, 25% Quantile and 75% Quantile of broiler production details during the study period: the number of birds delivered, number of DOA, the quantity slaughtered and the number of carcasses slaughtered.

	Median	25% Quantile	75% Quantile
Birds rejected on farm	177	103	291
Number of birds delivered	40 018	34 867	45 461
Mass of Birds (Kg)	1.73	1.64	1.82
Birds dead-on-arrival	104	51	209
Number of birds slaughtered	39 765	34 560	45 287
Number of carcasses rejected	56	33	93

4.3 The proportion of rejected broilers over the study period

There was a slight variation in the proportion of broilers rejected at the farm level, with the highest (0.59%, 95% CI: 0.586-0.594) observed in 2014, followed by 2015 (0.58%, 95% CI: 0.580-0.588) and the least (0.52%, 95% CI: 0.516-0.523) was recorded in 2016 (Figure 4.1). Likewise, there was a slight variation in the proportion of carcass rejects for the duration of the study period. The highest proportion of carcasses rejected was recorded in 2014 (0.28%, 95% CI: 0.273-0.278) and the lowest in 2015 (0.15%, 95% CI: 0.148-0.153).

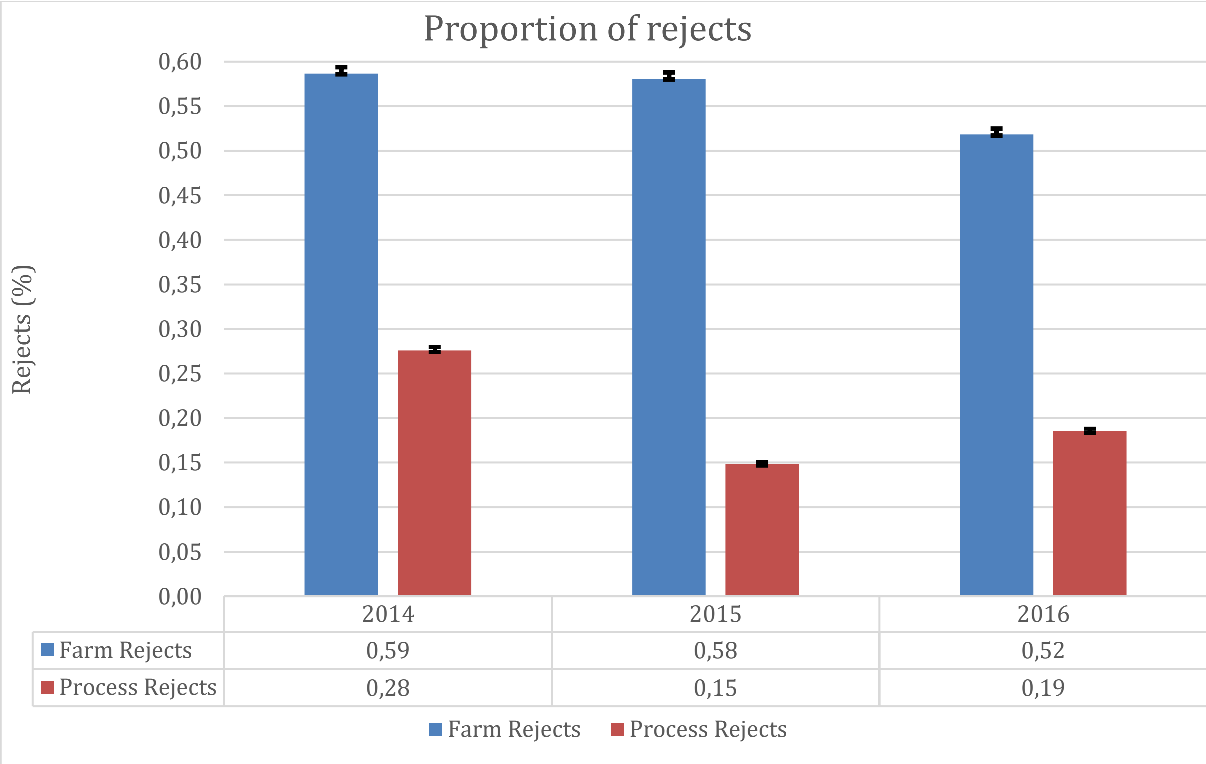

Figure 4.1: Bar graph showing the proportions of live broilers rejected at farms that supplied the abattoir with birds and carcasses rejected during processing at the abattoir between 2014-2016.

4.4 Dead-on-arrival

The proportion of DOA during the period of the study was 0.4847% (95% CI: 0.4825-0.4867). The highest proportion of DOA (0.56%; 95% CI: 0.5641- 0.5719) was recorded in 2014 and the lowest (0.36%; 95% CI: 0.4825- 0.4867%) in 2016 (Table 4.3)

Table 4.3: The distribution of proportions of DOA birds recorded during the study period by years (2014-2016).

Year	Dead-On-Arrival	95% Confidence Interval	
	n (%)	Lower	Upper
2014	81196 (0.5680)	0.5641	0.5719
2015	74163 (0.5130)	0.5090	0.5167
2016	47460 (0.3623)	0.3591	0.3656
Total	202819 (0.4847)	0.4825	0.4867

4.5 Annual trends of DOA over the study period

There was an upward trend in the proportion of DOA from November to January, followed by a decrease from January to April in 2014, 2015 and 2016 (Figure 4.3).

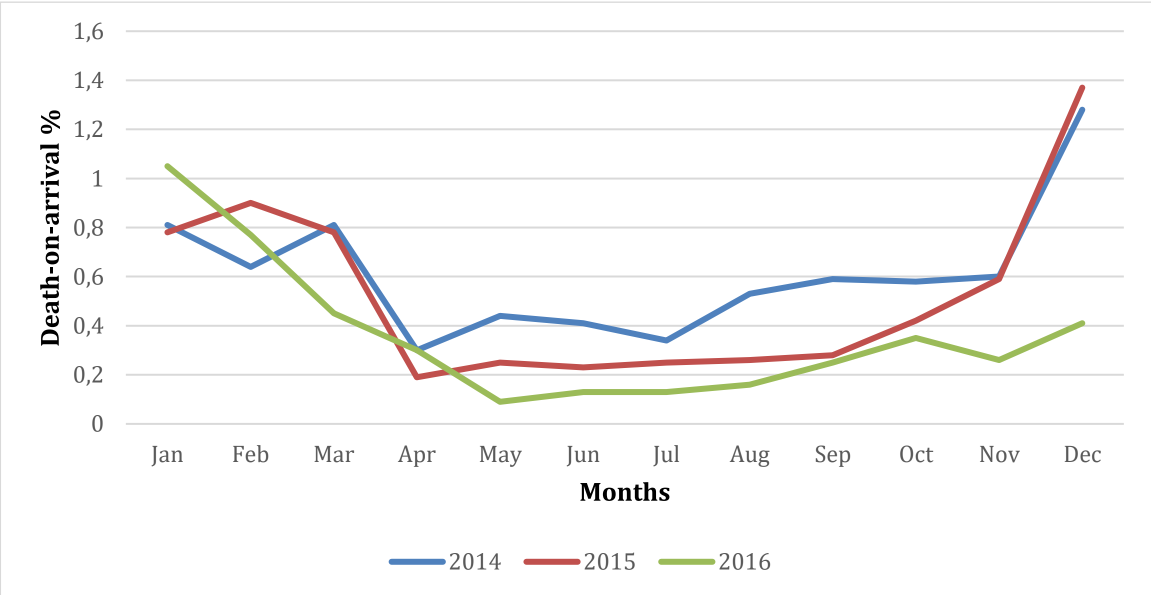

Figure 4.2: The annual trends of DOA birds that occurred during the period 2014 to 2016.

4.6 Distribution of DOA by seasons

The proportion of DOAs observed during the different seasons are summarised in Table 4.4. The highest proportion of DOAs were observed during the summer months (0.77%; 95%: 0.7695- 0.7789) followed by spring (0.41; 95% CI: 0.4082-0.4179) and Autumn (0.41%; 95% CI: 0.4069-0.4165). The winter months (0.26%; 95% CI: 0.2614-0.2667) recorded the lowest DOAs.

Table 4.4: The seasonal distribution of proportions of DOA birds that occurred during the study period.

Season	Dead-On-Arrivals	95% Confidence Interval	
	n (%)	Lower	Upper
Winter	37330 (0.2640)	0.2614	0.2667
Spring	27914 (0.4131)	0.4082	0.4179
Summer	109585 (0.7741)	0.7695	0.7789
Autumn	27990 (0.4117)	0.4069	0.4165

Winter= June, July and August; Spring= September, October and November; Summer= December, January and February; Autumn= March, April and May

4.7 Distribution of DOA birds by biosecurity on the farm

The farms without biosecurity facilities recorded higher proportions of DOA (0.5246%; 95%: 0.5206- 0.5285) as compared to farms that had implemented biosecurity measures (0.4674%; 95% CI: 0.4650- 0.4699) for the duration of the study period (Table 4.5).

Table 4.5: The Percentages of DOA birds by presence of biosecurity measures on the farm

Biosecurity	Dead-On-Arrival	95% Confidence Interval	
	n (%)	Lower	Upper
No Biosecurity	66052 (0.5246)	0.5206	0.5285
Biosecurity present	136767 (0.4674)	0.4650	0.4699

4.8 Distribution of DOA birds by capacity of the house

Houses with a carrying capacity of 38,000 birds reported a higher proportion of DOA (0.53%; 95% CI: 0.5223- 0.5289) as compared to houses with a carrying capacity of 48 000 (0.45%; 95% CI: 0.4499- 0.4553) (Table 4.5).

Table 4.6: Distribution of DOA by House Capacity for the period 2014-2016

House Capacity	Dead-On-Arrival	95% Confidence Interval	
	n (%)	Lower	Upper
38000	96422 (0.5256)	0.5223	0.5289
48000	106397 (0.4526)	0.4499	0.4553

4.9 Distribution of DOA birds by farms

Farms that were located more than 100km from the abattoir reported the highest proportion of DOA (0.5147%; 95% CI: 0.5897-0.7269). While those that were located within a distance of <100km reported the lowest proportions of DOAs (0.2756%; CI: 0.2334-0.3241) (Table 4.6).

Table 4.7: The distribution of DOA birds by distance between the farms that supplied the broilers and the abattoir where the broilers were slaughtered over the study period, 2014-2016.

Distance from farm to the abattoir (Km)	DOA	95% Confidence Interval	
	n (%)	Lower	Upper
<20	132 587 (0.5147)	0.5015	0.5282
20-39	64 532 (0.5048)	0.4931	0.5165
40-99	485 (0.2758)	0.2334	0.3241
100>	5215 (0.6486)	0.5897	0.7269

4.2 Inferential Statistics

4.2.1 Results of the negative binominal analysis: Factors associated with the occurrence of DOA.

The results of the negative binomial regression model as presented in Table 4.8 show that the rate ratio of DOA was significantly lower (IRR=0.502; 95% CI= 0.416-0.607; p<0.001) in winter season compared to the autumn. Meanwhile, the summer season had a significantly higher rate ratio of DOA (IRR=1.873; 95% CI=1.552-2.260; p<0.001) compared to autumn.

The rate ratio of DOA in 2016, was 1.7 times (IRR=1.742; CI=1.486-2.042; p<0.001) the rate ratio of DOA in 2014, and 1.5 times (IRR=1.462; CI=1.255-1.702; p<0.001) the rate ratio of DOA in 2015. However, the distance from farms to the abattoir was not significantly associated with the rate of DOA (p= 0.577).

If the mass of broilers was to increase by one unit (kilogram) the rate ratio of DOA would increase by a factor of 4 (IRR=3.785; 95% CI=2.480-5.776; p<0.001) while holding all other variables in the model constant. Likewise, if the number of broilers rejected on the farm was to increase by one unit, the rate ratio of DOAs would increase by a factor of 2 (IRR= 2.308; 95% CI= 1.624-3.281; p<0.001) while holding other variables in the model constant.

Table 4.8: Final results of the negative binomial regression model for DOA counts at the abattoir during the study period, 2014-2016.

Parameter Estimates				
Variables	**IRR[a]**	**95% CI[b]**		**P-value**
		Lower	**Upper**	
Seasons				
Winter	0.502	0,416	0,607	0.000
Spring	0.947	0,761	1,177	0.622
Summer	1.873	1,552	2,260	0.000
Autumn	Reference			
Years				
2014	1.742	1.486	2.042	0.000
2015	1.462	1.255	1.702	0.000
2016	Reference			
Distance Travelled				
<20km	0.963	0.844	1.099	0.577
>20km	Reference			
Birds Average Mass	5.706	3.696	8.738	0.000
Farm Rejects	2.308	1.624	3.281	0.000

a= Incidence rate ratio

b=95 percent confidence interval

Chapter 5: Discussion and Conclusion

5.1 Descriptive statistics

5.1.1 The occurrence of dead on arrival (DOA)

In this study, the percentage of DOAs was 0.48%. This is comparable to a percentage of 0.46% that was observed by Nijdam *et al.* (2004) in a study conducted between 2000 and 2001 in Belgium. Other researchers have also observed almost similar proportions of DOA birds in the Czech Republic. For example, Voslářová *et al.* (2007) reported a 0.52% of DOAs and Vecerkova*et al.* (2019) reported 0.59% of DOAs.

In contrast, some authors in England have reported lower proportion of DOAs compared what is reported in this study. For example, Warriss *et al.* (1992) reported 0.19% DOA and Warriss *et al.* (2005) reported 0.13% DOA among birds transported to the abattoir for slaughter. A lower DOA proportion of 0.30% was also reported in a study that compared post-mortem results in birds that died on farms and those that were DOA at the abattoir in Norway (Kittelsen*et al.*, 2017). Vecerek *et al.* (2006) in the Czech Republic also reported a lower proportion (0.25%) of DOA compared to that observed in the present study. Meanwhile, higher proportions of DOAs (1.22%) have been reported during the study of mortality of various types of birds in Italy (Petracci *et al.*, 2006).

According to Vecerek *et al.* (2006) the occurrence of DOA could be an indicator of poor animal welfare on poultry farms and during pre-slaughter processes. For example, Studies conducted in Sweden by Ekstrand (1998) observed that the number of recorded DOA was higher where there was incorrect mechanical catching of birds resulting in higher rejections of birds. The lower proportions of DOA observed in this study compared to what other studies have reported, could be attributed to the difference in the standard of animal welfare implemented on the farms in different countries.

On the other hand, the proportion of DOA reported in this study was higher than what was observed in studies conducted in England and Sweden (Ekstrand, 1998; Warriss *et al.*, 2005). These findings suggest that there is room for improvement on the farms under study. As a result, measures are needed to reduce the proportions of DOA by improving on the standard of welfare on farms under study.

5.1.2 Rejected birds

The proportion of birds rejected at farm level in this study was 0.56%, which is consistent with 0.56% farm rejects observed in a study conducted in Belgium by Jacobs *et al.* (2017). The findings reported in this study are also comparable to those observed in a study conducted in Netherlands by Nijdam *et al.* (2006) in which the proportion of farm rejects was 0.59%.

The observed differences in the proportions and number of broilers rejected on farms under study and those done elsewhere, albeit small, could be reflection of the difference in on farm management practices. According to Ekstrand (1998) farm management practices such as: feed withdrawal, catching and crating, cause stress, and an adverse energy balance that could lead to bruises, bone fractures or death, leading to increase in cases of farm rejects. Therefore, catching teams should be encouraged to handle birds with extra care during catching to minimise the number of birds rejected at farm level (Arbo, 2018). Furthermore, Nijdam (2006) also suggests that farm management practices have a huge influence on the proportions of rejects. The same author is of the view that farmers can reduce the negative effects of feed withdrawal by introducing an innovative type of diet made of semisynthetic ingredients which could be given to the birds days prior to catching.

5.1.3 Process rejects

Process rejects are carcasses that are deemed not to be suitable for human consumption due to predating conditions, such as emaciation, skeletal disorders, ascites, sudden death syndrome, and other bacterial infections (Nijdam *et al.*, 2006; Jacobs*et al.*, 2016). For the duration of the study period, 0.21% of the carcasses were rejected during processing in this study, which is lower than 0.88% that was observed in the study of pathological features in DOA broilers by Nijdam *et al.*(2006). Luptakova *et al.*(2012) in another study conducted in Slovak Republic between 2006 and 2010 also reported a higher proportion (0.73%) of process rejects.

Occurrence of process rejects has been attributed to transporting of birds on rural roads some of which are gravel roads that normally trigger wing flipping. Other factors include; inconsistency in the voltage used during stunning, very hot water during scalding and poor evisceration techniques. A study of rejected carcasses in Brazil, Santana *et al.*(2008) reported that the methods of catching, type of transportation and the temperature were the major causes of rejections in one of the abattoirs under study. The same authors reported bruises and fractures, cellulite, faecal contamination, bad bleeding and hepatitis as factors that accounted for carcass rejections. In other studies, Gregory and Austin (1992) explained that improper stunning prior to slaughter may damage the blood vessels and cause bruising, bleeding, discoloration and lump formation on chickens. Furthermore, the authors suggest that poor farm management, stress during transportation and other poor handling practices at the abattoir may also increase the proportions of carcasses rejected at the abattoir. Furthermore, differences in the quality standards used to judge process rejects from country to country could also explain the differences between the number of process rejects reported in this and other studies. For example, carcasses with torn skin may be considered as rejects in one country or abattoir while it is acceptable in others.

5.1.4 Temporal patterns

5.1.4.1 Annual variation

The proportion of DOA recorded during the study period decreased from 0.57% to 0.36%. A similar trend was reported in England, where the proportion of DOAs decreased from 0.15% in 2000 to 0.113% in 2002 (Warriss *et al.*, 2005). In contrast, in Italy the proportion of DOA increased from 0.35%, in 2001 to 1.22% in 2003 (Petracci, 2006).

The reason for a decrease in the proportion of DOAs observed in the present study could be attributed to the change in the way that farms are managed, improvement in animal welfare and the installation of biosecurity facilities on farms. Warriss *et al.* (2005) observed in their study of DOA broilers during transportation and in the lairage, that the care taken by chicken handlers during catching and improved animal welfare awareness enforced by management positively impacted on the occurrence of DOA over the years.

5.1.4.2 Seasonal variation

In this study most cases of DOA occurred during the summer months (December to February). This is consistent with what was reported by Vecerek *et al.* (2017); Xing *et al.* (2015) and Nijdam (2006) who investigated seasonal variances in the occurrence of DOA in the Czech Republic, China and Netherlands respectively. In all these studies, it was observed that more DOAs occurred in summer months compared to other months. The reason for more DOA cases in the summer months could be due to the high temperatures associated with heat stress in chickens, which in turn is associated with broiler mortality (Ritz *et al.*,2005). This is not surprising since broiler chickens are warm-blooded animals; they thus constantly produce heat to maintain a constant body temperature. Therefore, exposure to high temperatures alters the rate of the metabolic processes of the birds which may result in death (Kettlewell and Turner, 1985; Kannan *et al.*, 1997; Edgar *et al.*, 2013).

Low proportions of DOA that were observed during winter months in the present study could be attributed to the fact that winter temperatures are not very severe in the study area. In contrast, Caffrey *et al*, (2017) and Voslarova *et al* (2007) reported higher percentages of DOA during winter. According to these same authors, the very cold temperatures in winter months result in cold-stress that causes ascites in chickens which has been shown to have a significantly high association with DOA. Findings from the study of ascites syndrome in broiler chickens by Druyan (2012) support the observations made by Caffrey *et al.* (2017) and Voslarova *et al.* (2007).

Furthermore, results of the present study showed that autumn and spring experienced intermediate proportions of DOA as compared to what was observed in winter and summer. This could have also been attributed to the favourable temperatures that broilers experience in the area of study during the autumn and spring months.

However, the findings of the current study contradicted the findings by Vieira *et al.* (2011) who reported that proportions of DOA observed in autumn (0.23%) and winter (0.28%) were intermediate to those observed in spring (0.39%) and summer (0.42%). In fact, a study done by Petracci (2006) reported intermediate proportions of DOA in spring and winter. Reasons for the difference between results reported in this study and the other studies could be attributed to the climatic conditions in the study area which are semi-arid climatic conditions as opposed to the temperate weather experienced in other areas.

5.1.5 The capacity of houses

Chowdhury *et al.* (2012) reported that there was no significant difference between the cases of DOA from houses of different sizes. The same authors suggested that this could be because of the virtuous ventilation system used in poultry farms that render the conditions in the house uniform. In contrast, in this study, houses with larger capacity experienced lower proportions of DOA as compared to those that had a lower carriage capacity. On the other hand, finds of this study, contradict findings by Nijdam *et al.* (2004) who observed a higher proportion of DOAs from larger houses as compared to smaller houses. The authors attribute this to poor catching and feed withdrawal which tends to take longer in bigger houses leading to injuries, and hence increased risk of mortality.

5.1.6 The distance travelled by birds from farms to the abattoir

Farms farthest from the abattoir had the highest proportion of DOA (0.65%). These findings are in agreement with results recorded by Voslářová *et al.* (2007); Machethe (2016) and Warriss *et al.* (1992) who found that transporting chickens over longer distances was associated with considerable increase in the occurrence of DOA. Voslářová *et al.* (2007) also observed an increase in the proportions of DOA during transportation in summer and winter when birds had travelled longer and lower proportions of DOA when the distance travelled was shorter. Altogether, results of this study together with those from other studies, suggest that there are fluctuations in the cases of DOA in relation to the distance travelled by chickens from farms to the abattoir. This is corroborated by results of the study by Vecerkova *et al*. (2019); Fitzgerald (2017) and Oba *et al.* (2009) who found that the proportions of DOA related to the distance travelled by chickens fluctuated around the year. Reasons for the fluctuations in the occurrence of DOA with respect to the distance travelled are unclear and require further investigations.

5.2 Inferential statistics:

5.2.1 Seasons

Results of the Negative Binomial Regression model revealed that season had a significant association with the outcome variable (DOA), with the rate ratio of DOA being higher in the summer months compared to autumn. Given that the ventilation system is usually switched off during catching this may result in an increase in the temperature inside the houses more so during the hot summer months (Ritz *et al.*, 2005; Chowdhury *et al.*, 2012; Fitzgerald *et al.*, 2017; Vecerkova *et al.*, 2019). It is therefore possible that the majority of birds then die in the process of adapting to the higher temperatures they are subjected to during transportation. This could also explain the high DOA observed in the summer season (0.77%) as compared to the autumn season (0.41%).

In a study conducted in Britain, the proportion of DOA birds was found to double when temperatures were increased from 20°C to 23°C. Whereas in the same study, temperatures below 17°C were found to be more favourable to birds (Warriss *et al.*, 2005). It is therefore expected that commercial broiler abattoirs are likely to lose large numbers of birds during periods when ambient temperatures are higher. Thus, control measures need to be put in place to control the temperature during catching, transportation and while in the lairage, in order to reduce the number of birds that are lost as DOA (Mason, 2013; Mee, 2013). On the other hand, environmental conditions during winter and autumn are favourable for chickens; which explains why the number of DOAs was low during these seasons.

5.2.2 Years

Luptakova *et al*. (2012) in a study conducted in Slovak Republic between 2006 and 2010 observed that yearly differences could be due to changes in daily average temperatures for each year. But on the contrary, Warriss *et al*. (2005) are of the view that the dissimilarity in the rates of DOA observed over a three year period in their study, was probably not a reflection of higher ambient temperatures as the mean and variation in temperatures for those years were similar. In the present study, the years of study were significantly associated with the occurrence of DOA. The reason for different rates of DOA in this study between the different years is unclear. Assessment of daily temperature over the study period was outside the scope of this investigation. However, the difference in the number of birds delivered to the abattoir per year and the change in management team members (personal observations) could probably have impacted these results. This is partly supported by Jacobs *et al*. (2017) who observed that an increase in the number of birds delivered to the abattoir has the potential to increase the risk of occurrence of DOA.

5.2.3 The average mass birds delivered

Some authors have observed that the weight of birds harvested increases the risk of the occurrence of DOA among chicken being transported to the abattoir (Arikan *et al.*, 2017; Univer, 2016; Musilová*et al*, 2013). However, Vecerek *et al.* (2016) observed that the proportions of DOA decreased with an increase in the live mass of birds. The observation by Vecerek *et al.* (2016) has been attributed to the impaired health status of smaller birds, which may lower their ability to survive the stress during transportation (Julian, 1993; Haslam *et al.*, 2008; Arikan *et al.*, 2017; Caffrey, Dohoo and Cockram, 2017). In the present study, the live mass of birds harvested was significantly associated with the occurrence of DOA, in that with every increase in a kilogram of harvested broilers, the number of DOA was expected to increase by 6 fold. The congestion caused by loading birds in crates without taking into consideration the size of birds that are harvested on the day has also been reported as a factor. In the course of attempting to meet the high demand for chicken meat (Bolton, 2015), owners are forced to load the same number of birds in the same crates regardless of the body size or mass so as to deliver the same number of birds in each batch. This has potential to cause injuries and illnesses due to poor ventilation and heat stress. Actually some studies have reported that over 40% of broilers died from thermal stress due to poor ventilation in crates (Mitchell and Kettlewell, 1998; Vecerek *et al.*, 2016). In view of this, it is advisable that the weight of birds harvested should be kept very tight around the recommended harvesting weight (1.6-2.5 kg) of birds to prevent overcrowding and the risk of mortality associated with poor ventilation in crowded crates.

5.2.4 Farm Rejects

In the present study, for every increase in the number of birds rejected at farm level, the rate ratio of DOA counts increased by two fold. Other researchers have also made similar observations. For example, Haslam *et al.* (2008) in a study done in Britain observed a relationship between farm rejects and the number of DOA. Kittelsen *et al.* (2015) also observed that for every increase in the number of farm rejects, the number of DOA increased 9 times. The same author also observed that post-mortem tests done on farm rejects showed that the DOAs were caused by leg disorders, lung congestion, arthritis or other chronic diseases. At the point of feed withdrawal, catching, loading and transportation the affected birds become weaker and eventually die. In view of the findings of this study, farm rejects may be useful as an indicator of DOA. Therefore, care should be taken when catching, loading and transporting birds from farms with high proportions of farm rejects so as to minimise the number of DOA.

5.2.5 Distance travelled by chickens during transportation to the abattoir

In this study, the distance travelled by the birds was not significantly associated with the number of DOA. These results are contrary to trends reported by Voslarova (2007) and Vecerkova (2019) who observed that short distances were associated with lower rates of DOA; whereas longer distances were associated with increased rates of DOA. Some other studies suggest that distances above 150km are associated with greater increases in the occurrence of DOA (Warriss *et al.*, 1992a). Since the longest distance travelled in this study was 144km, this could explain why distance was not significantly associated with the cases of DOAs. In light of what is reported in literature, although the present study did not establish a relationship between distance and occurrence of DOA, there is evidence for a need for increased care for chickens transported over longer distances.

5.3 Conclusion and recommendations

Results of the current study together with scientific literature provided answers to questions that were asked in the first chapter of this report. The proportion of DOA among broilers slaughtered at the abattoir over the study period although higher than was observed in some studies was consistent with what others have observed elsewhere. Furthermore, findings reported here show a decrease in the proportion of DOA over the study period; 2014-2016, which is suggestive of improved management and the welfare of birds over the study period.

The occurrence of DOA at the chicken abattoir was strongly influenced by summer seasons due to high temperatures that lead to heat stress. However, the impact was less over the cooler seasons of the year (winter, autumn and spring). Other factors such as live mass of birds and the crate capacity also impact the number of DOA. There is a need to reconsider the practice of carrying the same number of birds per crate without giving regard to the mass of the birds. The number of farm rejects serves as a good indicator of the occurrence of DOA due to the strong positive association between the two. Therefore, if large numbers of farm rejects are observed care must be taken to ensure that the number of DOAs is kept to the minimum. This can include taking more care when catching and loading birds. Although the association between explanatory factors such biosecurity, the capacity of farmhouses and the distance travelled by birds from farms to the abattoir and the outcome variable (DOA), was not significant, further studies are recommended to confirm the findings reported in this study.

In light of the findings reported in this study, the majority of birds should be delivered/ transported to the abattoir early in the morning before it gets too hot and late at night when the temperatures have decreased to around 17°C and below. The weight of the birds on the farm should be maintained as close to the recommended harvesting mass as possible to prevent congestion in crates.

Measures to improved animal welfare throughout the process (from farming to slaughtering) and care during handling of birds particularly on farms with high numbers of farm rejects should be implemented to lower the number of DOA. Lastly, there is a need to ensure sufficient ventilation in houses (during catching), transportation (in crates) and at the abattoir (in the lairage).

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Appendix 1: Ethics Approval Letter

UNISA university of south africa

UNISA CAES GENERAL ETHICS REVIEW COMMITTEE

Date: 08/09/2017

NHREC Registration # : REC-170616-051
ERC Reference # : 2017/CAES/130
Name : Mr TR Shokwe
Student #: 61942855

Dear Mr Shokwe

Decision: Ethics Approval from 07/09/2017 to 30/09/2018

Researcher(s): Mr TR Shokwe
tumelo.shokwe@rclfoods.com

Supervisor (s): Dr JW Oguttu
joguttu@unisa.ac.za; (011) 471-3353

Working title of research:

Predictors of death on arrival (DOA) among chickens slaughtered at a poultry abattoir in Mopani District of Limpopo Province, South Africa

Qualification: MSc Agriculture

Thank you for the application for research ethics clearance by the Unisa CAES General Ethics Review Committee for the above mentioned research. Ethics approval is granted for a one-year period. After one year the researcher is required to submit a progress report, upon which the ethics clearance may be renewed for another year.

Due date for progress report: 30 September 2018

Please note the points below for further action:

1. The researcher is cautioned to adhere to the stipulations in the permission letter from the company.

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
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*The **low risk application** was **reviewed** by the CAES General Ethics Review Committee on 07 September 2017 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Committee.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
5. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
6. No field work activities may continue after the expiry date. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

*The reference number **2017/CAES/130** should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

Prof MA Antwi
Acting Chair of CAES General ERC
E-mail: antwima@unisa.ac.za
Tel: (011) 670-9391

Prof MJ Linington
Executive Dean : CAES
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Appendix 2: Letter Granting Permission to use the data

07-06-2017

Permission for data usage

To whom it may concern,

This letter serves as confirmation that Tumelo Shokwe is allowed to make use of the Agricultural and Processing data from RCL Foods for use in his thesis. This permission is given on the condition that RCL Foods is not mentioned by name within this document or any scientific papers, and that RCL Foods reserves the right to scrutinize these documents and remove any part they may deem unfit before their final submission to Unisa.

Kind regards

TARYN HALSEY
OPERATIONS MANAGER - TZANEEN
Consumer Division

Tumelo permission document.docx
Rev No: 00 07/06/17

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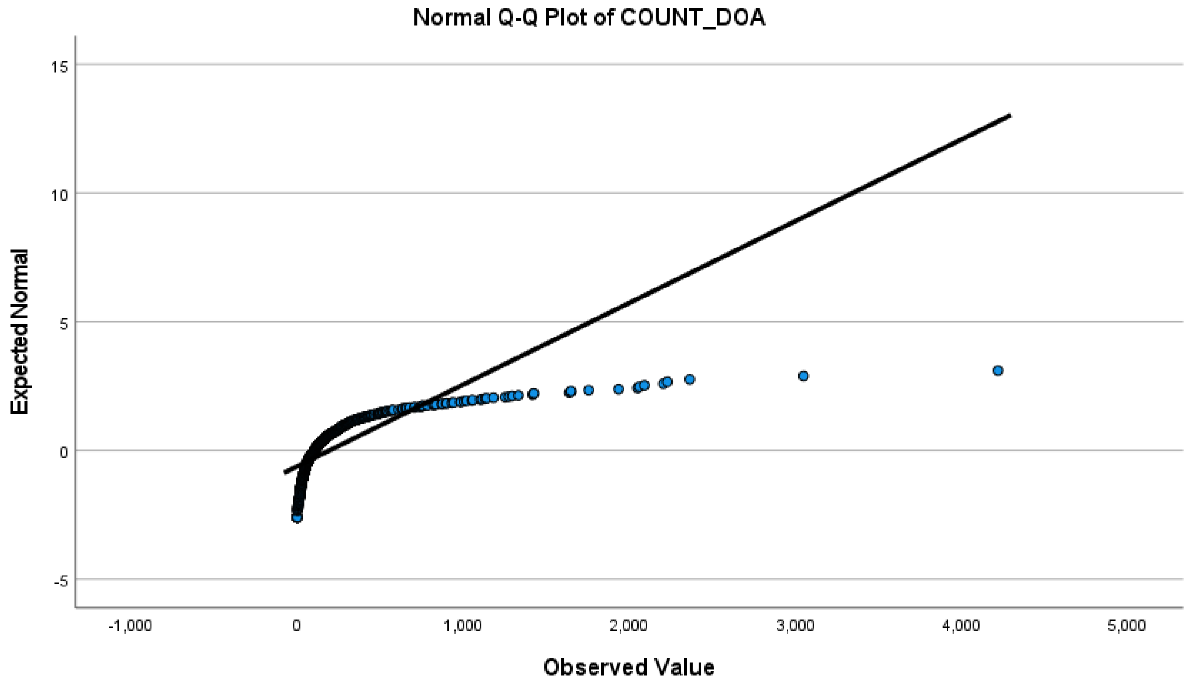
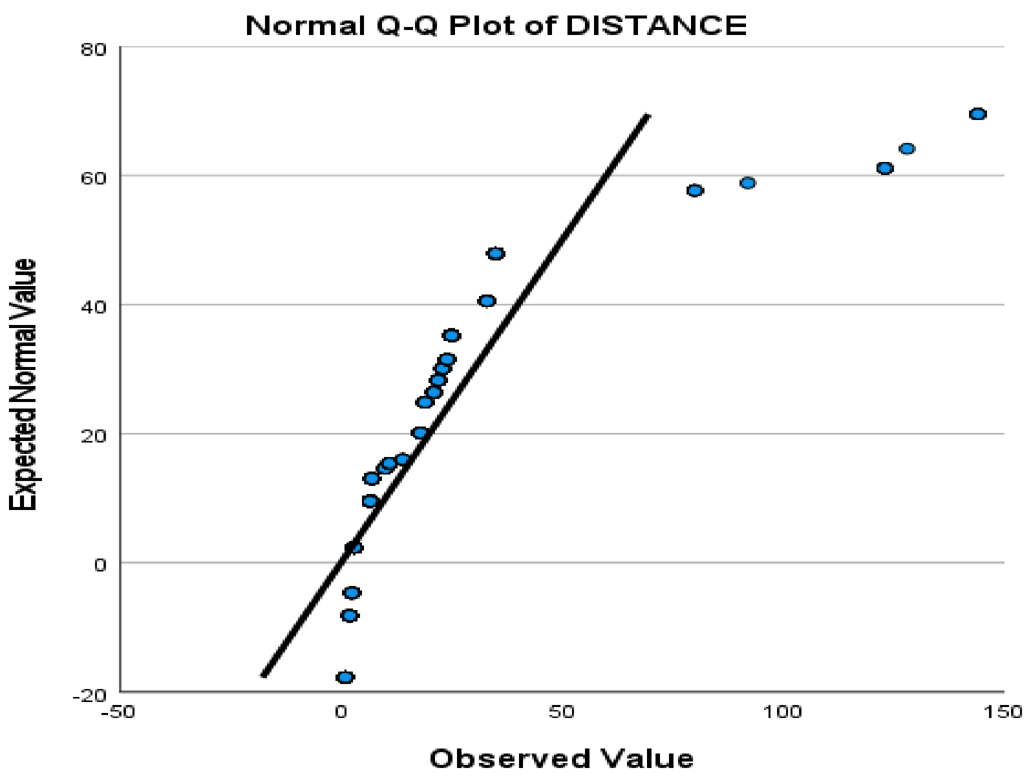
Appendix 3: Normality Test for variables included in the model

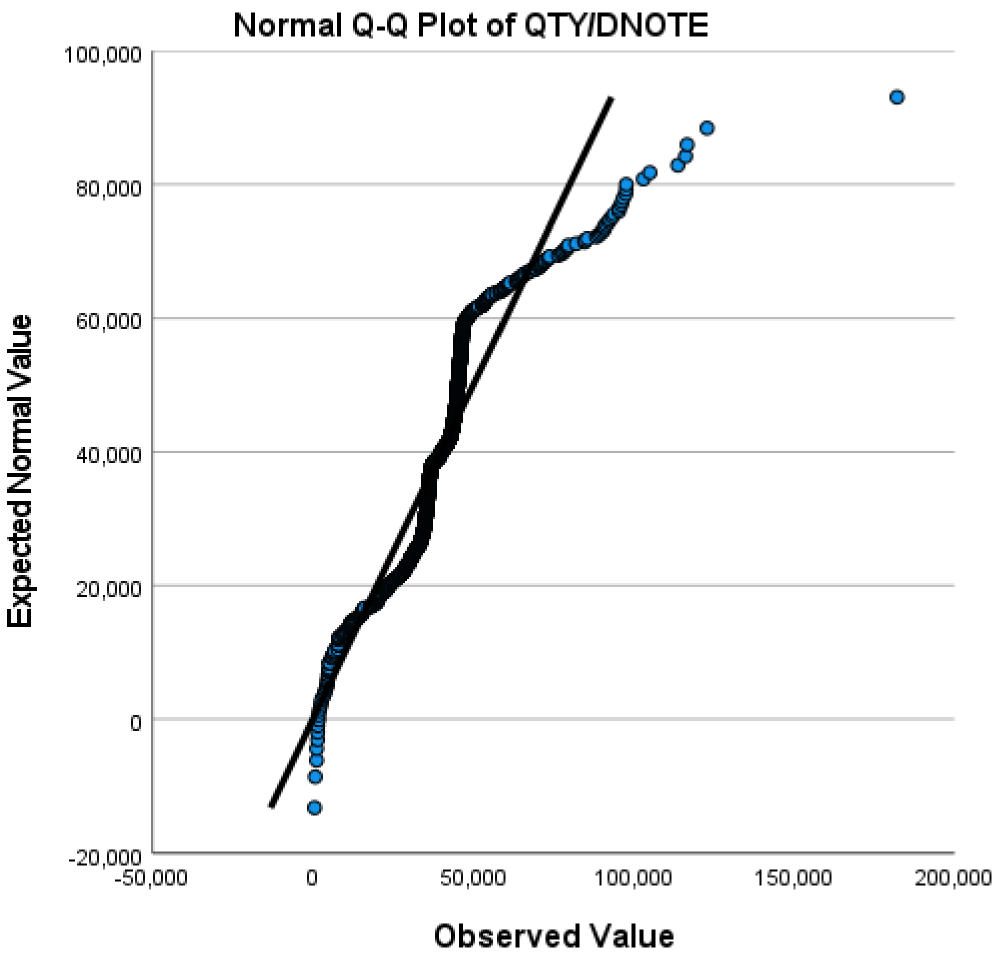
Normality test results of Count DOA



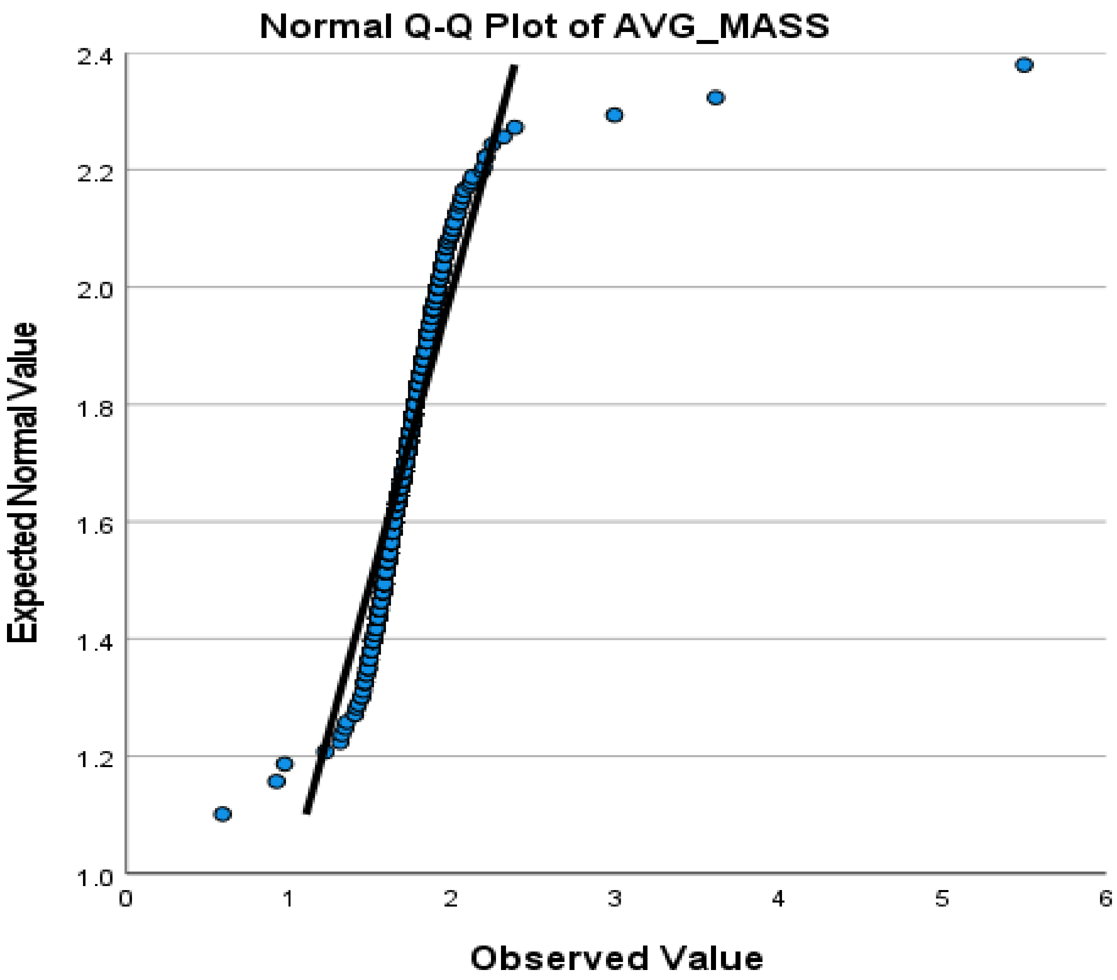
Normality test results of Distance



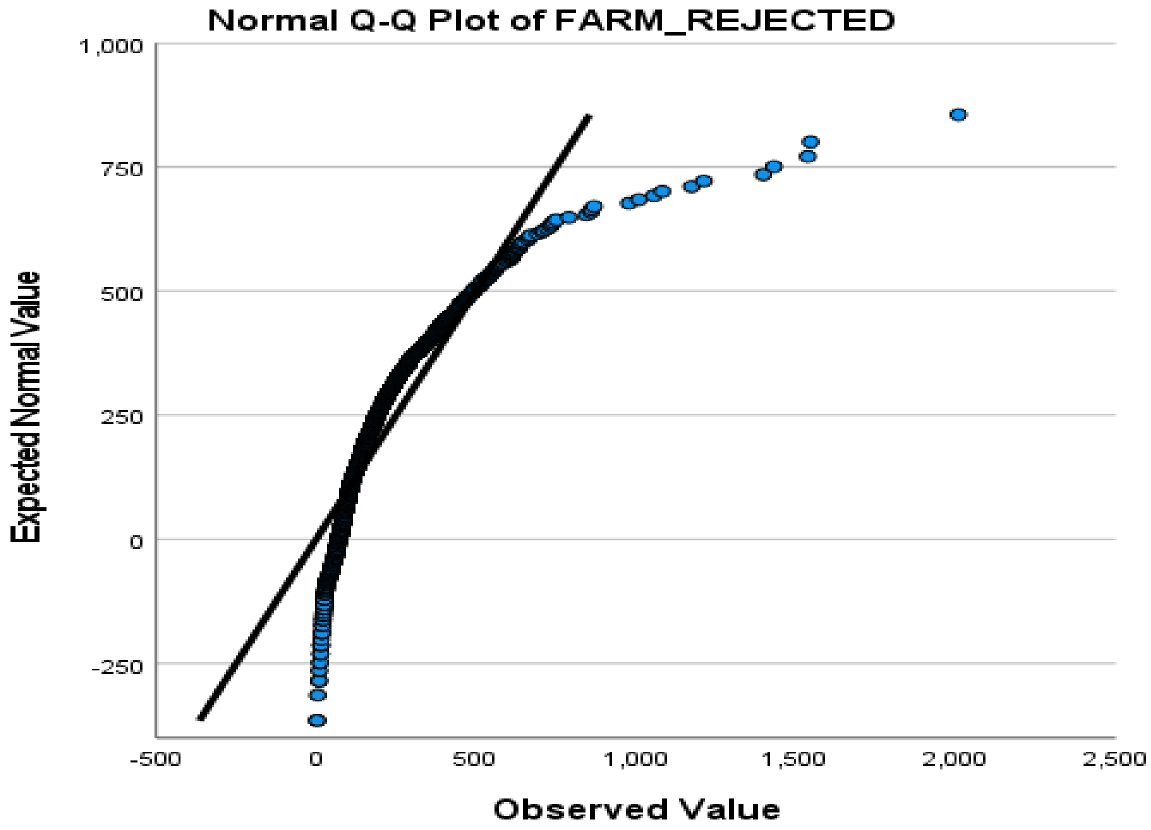
Normality test results of Quantity of birds delivered



Normality test results of live birds' average mass



Normality test results of Quantity of birds delivered



Appendix 4: Model diagnostics results

Comparison of models

	Model 1[a]	Model 2[b]	Model 3[c]	Model 4[d]	Final Model
Value/df	0,786	0,785	0,786	0,786	0,785
Akaike's Information Criterion	12523,278	12521,284	12540,591	12539,681	12520,033
Pearson Chi-square	1513.511	1513.568	1518.525	1519.932	1515.903
Omnibus Test Chi-Square	340,802	340,796	341,437	340,346	340,047

Omnibus Test of model effects for the final model

Likelihood Ratio Chi-Square	df	P-value
340,047	8	0.000

[a] Model with all variables with p-value= <0.20
[b] Model without 'Biosecurity'
[c] Model without 'Biosecurity' and 'Distance'
[d] Model without 'Biosecurity', 'Distance' and Capacity

Appendix 5: Results of the univariate models for each potential predictor with broilers that were DOA (outcome variable) at the abattoir during the study period

Parameter Estimates (Univariate)				
Parameter		**95% CI[f]**		**P-value**
	IRR[e]	**Lower**	**Upper**	
Seasons				0.000
Winter	0.571	0.475	0.687	0.000
Spring	0.914	0.738	1.131	0.407
Summer	1.720	1.430	2.070	0.000
Autumn	Reference	-	-	-
Years				0.000
2014	1.662	1.429	1.932	0.000
2015	1.389	1.195	1.615	0.000
2016	Reference			-
Biosecurity				0.000
No	1,134	0,993	1,294	0.062
Yes	Reference	-	-	-
Capacity				0.000
Yes	1,217	1,077	1,376	0.002
No	Reference	-	-	-
Distance Travelled				0.000
<20km	0,882	0,775	1,003	0.056
>20km	Reference	-	-	-
Birds Average Mass	1,561	1,066	2,286	0.022
Farm Rejected	1,001	1,000	1,001	0.000

[e] Incidence rate ratio
[f] 95 percent confidence interval