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Research Paper

Evolution in Broiler genetics, Provides Improved Performance Economically

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ABSTRACT
This study is a brief and specific explanation of the contribution of breeding to improving the performance of broiler chickens in achieving chicken meat production according to market needs and profit goals for the livestock industry. The increase in demand for broiler chickens continues to increase. The level of consumption achieved in America from 1992 to 2022 Broiler reached the highest position, namely the achievement value increased by 52.4% compared to Beef, Pork, Turkey and others Chicken. Progress in the growth of broiler meat production is driven by advances in selection programs in genetic improvement of broiler growth performance. The process of setting breeding goals involves a blend of economics, science, and consumer psychology. Commercially produced broilers are always a cross of at least three or four lines. Female lines must have good egg production and high hatchability as well as the best weight gain and feed conversion. Male line strains should have the best weight gain, feed conversion ratio, with a broad chest and muscular appearance. The main objective of this growth selection is to increase the profitability of broiler production. Research shows the growth rate of broiler chickens increased more than 400% between 1950 and 2005. 1991 Arbor Acres (AA) chickens weighed more than 1957 Athens-Canadian Randombred Control (ACRBC) chickens, regardless of feed. At eight weeks of age, the 1991 chickens weighed approximately 4 pounds more than the 1957 chickens. The 1991 chickens were more efficient at converting feed into meat than the 1957 birds. At 4 weeks of age, the relative body weight of the 1978 strain chickens Alberta Meat Control (AMC) reached a high of about 43% of the 2005 strain's body weight, and the relative body weight of the AMC-1957 strain reached a high of about 21% of the 2005 strain's body weight.

Keywords*: Broiler, Breeding, genetic, performance, ekonomy.*

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I. INTRIDUCTION

Broiler is the most popular term for broiler chickens. The term Broiler appears to originate from the eastern USA where it describes young chickens aged (10-12 weeks) which are most often prepared by splitting the chicken lengthwise and "Broiling" over an open fire (Leeson and Summers, 2009). Broiler chickens or broiler chickens are a poultry commodity resulting from the livestock breeding process, namely by development through improving genetic performance through cross-breeding, strict selection and carried out in a sustainable system so that genetics with good growth performance are obtained (Triastuti et al., 2023). In breeding programs, the characteristics of male lines related to growth receive the main emphasis. Traditionally, growth rate or more specifically body weight at a certain age has been the main selection criterion. In the early days of broiler strain development, it was quite easy to make rapid progress with this trait (Lesson and Summer, 2009).

Commercially bred broiler chickens are usually a cross of a parent breed and a special breed parent. The position of a purebred line in the crossing system influences its genetic contribution to the expression of productive and reproductive performance (Jiang, *et al.*, 1999). This also includes morphological differences such as changes in feather color, reduction in skull size, and changes in body size. Observed behavioral differences include more docile and docile individuals, with lower fearfulness. Physiological changes also

occur, including weakening of physiological stress responses and changes in reproductive cycles (Wilkins *et al.*, 2014).

The increase in demand for broiler chickens continues to increase from year to year. Chicken meat is considered a source of animal protein that is quite familiar in all levels of society in all parts of the world with its tender and cheap meat. Based on statistical data according to the National Chicken Council (2023), the highest per capita meat consumption level in 1992 in America was Beef 65.9 pounds compared to Pork, Broiler, Other Chicken and Turkey. In 2022, Broiler will have the highest per capita consumption at 98.9 pounds compared to Beef, Pork, Other Chicken and Turkey (Table 1).

Table 1.Percapita Consumption Poultry and Livestock (pounds) in 1992 and 2022.

Meat	1992	2022	Consumption Increase (%)
Beef	65.9	59.1	-10.3
Pork	52.3	51.1	-2.3
Broiler	64.9	98.9	52.4
Others Chicken	1.60	1.70	6.2
Turkey	17.8	14.6	-18.0

Source: National Chicken Council (2023).

Table 1 shows that the percent consumption achievement from 1992 to 2022 or for 20 years, Broiler was able to reach the highest position, namely the achievement value increased by 52.4% followed by Others Chicken 6.2% while Beef, Pork, Turkey actually experienced a decrease in achievement respectively by 10.3%, 2.3%, and 18%. Americans' per capita consumption of poultry products has increased dramatically, while per capita beef consumption has declined. Economists have proposed a number of hypotheses to explain the changing substitution of poultry for American consumers. Applied analysis focuses on factors such as relatively lower poultry prices and changing consumer preference structures due to health concerns. However, time constraints imposed by the increasing number of women in the workforce can also direct meat consumption towards the dominant poultry product category, namely a category that prefers quick preparation and fast food options (Haley, 2001).

The data above shows the progress in the growth of broiler meat production which is quite successful, this is driven by the progress of the selection program in genetic improvement of broiler growth performance over time. According to Zhai (2018) Broiler chickens are a type of poultry used in the poultry industry, and their sole purpose is to produce large quantities of meat in a short time. If an industry is able to breed large chickens in a short time, production costs will be lower, resulting in a cheap product for consumers.

The following discussion is a specific study to briefly explain the details related to improving the performance of Broiler chickens in achieving chicken meat production according to market needs and profit goals for the livestock industry so as to produce safe and healthy products at affordable prices for the community. The consequences of developments in breeding technology have made a major contribution to changing the characteristics of broiler chickens into livestock that are efficient in growth, thus having an impact on economic values and are the focus of this review.

II. BROILER BREEDING METHODS

2.1. Chicken Domestication

Modern chickens are believed to originate from four species of wild fowl, namely the Red Junglefowl (Gallus gallus), Javanese Junglefowl (Gallus varius), Gray junglefowl (Gallus sonneratti) and Ceylon junglefowl (Gallus lafayetti) (Ashraf and Rehman, 2017) . Genetic evidence confirms that chickens were domesticated from forest fowl, of which there are four species (grey, Ceylon, green and red). There is much disagreement regarding the forest species to which birds contributed their genetic material to today's chickens (Barber, 2018). Most likely of the four wild species the Red Forest Fowl (Gallus gallus) is the main ancestor. Chicken breeds used today in commercial farming are thought to originate from the Red Forest Fowl (Gallus gallus) (Laughin, 2007).

A junglefowl subpopulation that took refuge in India has been considered the primary origin of modern Gallus, but the contribution of a possible third refugia subpopulation in Asia is not excluded. As a result, the wild ancestors of modern chickens all came from India and Southeast Asia. Four living wild Gallus species are known, namely Gallus gallus, Gallus sonneratii, Gallus varius and Gallus lafayetii which differ based on their morphology and geographical distribution in Asia (Tixier-Boichard, *et al.,* 2011). It is believed that modern chickens originate from chickens kept based on archaeological finds by the people of the Harappan culture of the Indus valley (2500-2100 BC), primarily for fighting purposes (Laughlin, 2007; Zeuner, 1963).

Thus, chickens have been domesticated for around 4000 years and it can be assumed that during this time period there has been selection for desirable characters (Laughlin, 2007). The accumulated effects of domestication and subsequent selection by humans have resulted in an impressive phenotypic diversification of

chickens, both at the morphological and physiological levels (Tixier-Boichard, *et al*., 2011). Selection for certain phenotypic characters (comb type, feather color or length) was carried out by mating only from individuals displaying the desired character long before Mendel's work on inheritance explained the possible mechanisms (Laughlin, 2007). Four types of domestic populations can be considered depending on their selection history, namely traditional populations, standardized breeds, selected lines (either experimental or commercial) and experimental inbred lines (Tixier-Boichard, *et al.*, 2011). Genomes from modern chicken stocks used for meat production confirm the major role of Asian heavy chicken breeds in modern broiler chickens (Guo *et al.*, 2021)

There are four main classes of chickens found throughout the world, namely: American, British, Mediterranean and Asian (table 2).

Table 2. Distinguished characteristics of poultry classes.

Characteristic	American	English	Mediteranian	Asiatic
Body size	Medium	Medium	Light	Heavy
Purpose	Dual	Dual	Egg	Meat
Shell colour	Brown	Brown	White	Brown
Ear Lobe colour	Red	Red	White	Red
Skin Colour	Yellow	White	Yellow	Yellow
Feather on Shank	No	No	No	Yes

Source: Hag and Akhtar (2004).

2.2. Commercial Breeding Programe

For thousands of years, chickens were bred not for their qualities to produce human food but for their fighting abilities and their value as novelties such as oddly shaped combs, the presence of crested feathers on the head, feathers on the legs (Saunders, 2022), also used in religious ceremonies dedicated to sacrificed to the sun god (Parkhurs and Mauntney, 1988). Humans have made many genetic changes during the domestication process and since then by developing local varieties and selecting for various traits. Genetic advances achieved since the late 1950s have become the foundation of the modern poultry industry which is the main source of animal protein in most countries in the world (Crawford, 1990). Global trends since the early 1950s according to Arthur and Albers (2003) are as follows.

1. Broiler growth has consistently been the main characteristic of selection, due to ease of selection, high heritability, and large impact on total meat production costs.
2. The emphasis on white meat (breast meat) is increasing, because this is increasingly preferred by consumers.
3. There is also increasing emphasis on one efficiency factor, particularly feed efficiency in growing broiler chickens, as the maturing production industry increasingly focuses on financial returns for integrated production operations.

The most historic breed of chicken is 'dual purpose', which means it was bred for both meat and egg production. It was only when commercial chicken farming intensified in the late 1950s that breeds were developed specifically for one purpose or another (Barber, 2018). Breeding objectives provide the guidelines that direct a breeding program and identification of breeding objectives is an important starting point for the success of a breeding program. The process of setting breeding goals involves a blend of economics, science, and consumer psychology. The poultry industry is a highly competitive business and, as a consequence, decisions regarding poultry farming are driven by economic factors. The sciences of genetics and physiology provide the basis for efficient genetic change, therefore, these disciplines are key components in developing breeding objectives (Emmerson, 2003).

A number of broiler breeding companies have been established since the late 1940s and have made a major contribution to the genetic improvement of broiler chickens over the years. These companies are mainly located in the United States (North America) and Europe (UK). The three largest broiler breeding companies in the world are Aviagen (Ross, Arbor Acres and Indian River), Tyson (Cobb-Vantress and Avian) and Hubbard-ISA (Hubbard and Shaver) (Flock and Preisinger, 2002). Large primary breeding companies typically have staffs that include geneticists, veterinarians, nutritionists, and general management specialists. These professionals act as a team to develop new strains and management techniques to optimize their performance (Bell and Weaver, Jr., 2002).

A comprehensive summary of the main contributions to the development of modern breeding programs has been presented in Table 3.

Table 3. Breeding selection methodology.

Selection Methode	Times Period
Mass Selection	1900
Trapnesting	1930
Hybrid Crosses	1940
Artificial Insemnination	1960
Family feed conversion	1970
Individual Feed conversion	1980
BLUP Breeding value estimation	1990
DNA Markers	2000

Source : Arthur dan Albers (2003).

It is important to remember that along with the development of genetics, various reproductive technologies emerged, for example artificial incubation and hatching, lighting programs to allow year-round production and artificial insemination were developed. These techniques are also important for enabling the development of poultry breeding programs and production industries. It is difficult to say exactly when modern broiler farming began because there have been a number of important developments (Laughlin, 2007). Much progress has been made in artificial selection technology over the last century: from mass selection to the use of pedigree charts and hybridization, to the introduction of selection indices and artificial insemination, to the development of modern breeding value estimation techniques (Rishell, 1997; Muir and Aggrey 2003).

2.3. Broiler Purebreed

In the broiler chicken production system, production and reproduction characteristics are expressed at different stages. Production traits are only expressed at the commercial breeding stage, while reproductive traits are expressed at the pure line and multiplier stages. In broiler breeding, selection is carried out at the pure line stage (purebred), while the aim of breeding is to improve performance. Crossing is carried out on commercial farms and at the multiplier stage. Commercially produced broilers are always a cross of at least three or four lines. The lines to be crossed and the order of crossings are carefully evaluated and selected based on their ability to meet market demand (Hiemstra and Napel, 2013).

Female lines must have good egg production and high hatchability. In addition, it must have good weight gain, the best feed conversion ratio, and the best feed efficiency. Male lines should have more weight gain, best feed conversion ratio, with broad chest and muscular appearance. Cornish is used for meat lines. The variety produces synthetic lines that have broad chests, short legs and plump carcasses. Apart from these characters, you must be a good producer with good hatchability. White feather flesh lines are preferred because they are easy to process in commercial plants. Yellow and white skin color If white skin is preferred then the male line is crossed with Sussex or New Hampshire which has white skin and white skin is dominant over yellow skin (Ashraf and Rehman, 2017). The lines that are usually used in broiler crossings are:

2.3.1. New Hampshire (Female Line)

New Hampshire has a pink color, yellow skin, a single comb, and produces light brown eggs. At first New Hampshire was famous for its high egg production, but later became known as a chicken with good meat quality. This chicken is a superior breed in the production of broiler chicks. New Hampshire females are crossed with males of other meat varieties to produce crossbred broiler chicks (Bell and Weaver, Jr. 2002). Females of this New Hampshire breed are used for broiler production because of their high egg production with good hatchability, meat quality, fast growth, fast feathering, early maturity and strength (Ashraf and Rehman, 2017) and have good carcasses and plump good as a broiler (Ministry of Agriculture, 2010). New Hampshire females are crossed with males of other meat breeds to produce crossbred broiler chicks (Ashraf and Rehman, 2017). Also used in early-stage broiler breeding programs, New Hampshire has reasonable growth characteristics as well as good egg production and hatchability (Lesson and summer, 2009), making it a valuable asset for many breeding combinations (Bell and Weaver, Jr. 2002).

The dual-purpose chicken was developed in the United States and named after its country of origin. New Hampshires were created through selective breeding of the Rhode Island Red to increase growth rates and muscle growth rates for use in the broiler industry and are therefore more suitable than the Rhode Island Red (Damerow, 2012). Competitive and aggressive New Hampshires were originally used in the Chicken of Tomorrow contest, which led the way for the modern broiler industry (Skinner and Hady, 2018), and were accepted into the Standard in 1935 (Ministry of Agriculture, 2010).

2.3.2. White Plymouth Rock (Female Line)

White Plymouth Rock has yellow skin and a single comb. Although pure varieties were used by early broiler breeders, they now form the basis of many synthetic lines. White feathers benefit commercial broiler production and processing plants, which do a better job of selecting chickens with white feathers over those with

colored feathers (Bell and Weaver, Jr. 2002). Its body is long, deep and full, making it a popular multi-purpose chicken with yellow skin and calves and brown egg shells (Ministry of Agriculture, 2010). Females of this breed are used for commercial broiler production (Ashraf and Rehman, 2017) and were developed in the New England United States in the 1870s to become the female line of choice in most breeding programs. Its main advantage is its white feathers, and although initially most chickens had slow feathering, this characteristic was quickly converted into a fast feathering allele (Lesson and Summer, 2009).

The large, fleshy, dual-purpose strain of the type was developed in Massachusetts and named after the large rock on which the Pilgrims first landed in Plymouth, Massachusetts. The Plymouth Rock is a strong, docile breed with a single comb (Damerow, 2012). White Plymouth Rock females are used as the female side of most commercial broilers produced today and usually make good brood hens. Generally, Plymouth Rocks are not very aggressive, and they are tamed quite easily (Skiner and Hady, 2018).

2.3.3. Cornish (Male Line)

Cornish hens have pea combs, lay brown eggs, and yellow skin. They have a very different body type than most other breeds. The legs are short, the body is wide, and the chest is very broad and muscular. Cornish traits are desirable from a meat perspective, but the birds lay few eggs with poor hatchability (Bell and Weaver, Jr. 2002).

The Cornish breed is the foundation of our modern broiler industry. This is the champion of the chicken world. This muscular, fierce looking bird, was developed in Cornwall, England, and has a strong game fowl heritage, which is the origin of its alias, Indian Game (Ekarius, 2007). The different names for this breed of chicken represent its history: bred in Cornwall England from chickens imported from India. Early 'Cornish Indian Game' was used for cockfighting, but since around 1880 it has been bred for exhibition or for breeding broilers (Scrivener, 2009). This breed was developed because of its abundant amount of breast meat, so that no other breed can match it. When broiler chickens became the most popular in the country, male Indian Game chickens were chosen as mates for females of broiler breeds such as the Sussex, Dorking, and Orpington, to produce extra large crossbreeds. The females selected for mating come from breeds that have white flesh and calves (Roberts, 2008).

Cornish have short legs, a wide body and a wide, muscular chest, but these chickens produce only a few eggs and have poor hatchability (Ashraf and Rehman, 2017). With its white feathers and yellow skin, the White Cornish offered great potential for developing white-feathered broiler chickens in the 1920s-1930s. With relatively short legs and a broad, muscular chest, this strain quickly became a major contributor to male lines in breeding programs. Due to its relatively poor egg production, Cornish was little used in the 3- or 4-way crossbred female lines that later became the most popular breeding system (Lesson and Summer, 2009). Developed as the best broiler chicken, the Cornish has contributed its genes to build the world's largest broiler industry. The development and organization of the muscles provides excellent carcass shape (Skiner and Hady, 2018).

2.3.4. Sussex (Male Line)

The Sussex is a largely British meat breed with several varieties, and the Light Sussex is the most popular. Its skin is white, its eggs are brown, and it is a good meat producer. In England and several European countries, white-skinned broiler chickens are preferred over yellow-skinned ones (Bell and Weaver, Jr. 2002). This type of rooster has more body weight gain, a wide and muscular chest. The male broiler chickens that are bred are white-skinned broilers (Ashraf and Rehman, 2017). Common use of Sussex is to produce meat and/or eggs. Sussex originate from the county of Sussex in England, where they were prized as table fowl more than 100 years ago. They continue to be a popular fowl in the UK, and light varieties have featured prominently in the development of many commercial strains (Skiner and Hady, 2018). Sussex is an old breed with a dual function that originates from the Sussex area in England, where this large-bodied chicken is kept mainly for meat (Damerow, 2012) which is crossed with Indian Game for meat (Roberts, 2008).

Sussex is closely related to Dorking; historical evidence suggests that Sussexes were selectively bred from four-toed Dorkings. The Sussex has a single comb, may be large or bantam, and is available in several color variations, the original being spotted. Hens have good egg layers with light brown shells. The light and white varieties are the best laying hens, but rarely go broody, while the spotted varieties grow less well but are more likely to breed, and are good parents (Damerow, 2012). Light Sussex is somewhat comparable to New Hampshire in the US, in providing a breed that can be used in both male and female lines (Lesson and summer, 2009).

2.3.5. Broiler Breeding Structure

Broiler breeding consists of selecting genetically pure lines to obtain desired characteristics and characteristics multiplying and crossing these lines in three to four steps to breed commercial broiler chickens

(Hiemstra and Napel, 2013). Genetic improvements that occur in the Pedigree population are passed down through a doubling process as quickly and efficiently as possible. At each generation in the duplication process, there is a dilution of genetic improvements because selection is minimized or absent, and because of meiotic recombination. Typically, this is a 4 year process that results in a "genetic time lag". The shorter the genetic time lag, the faster the change occurs from a pureline pedigree population to a crossbred broiler population (Pollock, 1999). Therefore, the involvement of these special lines in the development of commercial broiler stocks will progress rapidly towards reducing production costs. Crossing these diverse genetic lines results in gene recombination that produces heterotic effects in offspring for different economic traits. Therefore, intensive selection of pure lines and crossing lines that have genetic diversity are the most characteristic features in broiler breeding programs. When practicing artificial selection, care is taken to minimize inbreeding, and its associated consequences on the population. A control population with the same increase in inbreeding as the selected population can be maintained for comparison and evaluation of the selected population (Saxena and Kolluri, 2018).

Genetic selection, based on the performance of the chicken itself and its relatives, is carried out at the Pedigree breeding location. Doubling and crossing occurs in breeding facilities, where only chickens that show abnormalities are to be rejected. This structure is referred to as the broiler breeding pyramid (Fig. 1). Structures for producing large numbers of crossbred broiler chickens are traditionally represented as pyramid farms, indicating that the number of chickens in genetic selection programs at the top of the breeding pyramid is very small compared to the number of crossbred broiler chickens (Hiemstra and Napel, 2013).

The traditional way to describe a reproductive system is to use a pyramid (Fig. 1). Identifies the pedigree program as the pinnacle and expands its level as it passes through Great Grand Parent (GGP), Grand Parent (GP), Parent Stock (PS) and commercial (Broiler) production. An operating time scale can be added to this to give an indication of the importance of both. Typically describes a situation where the time from pedigree selection to commercial broilers is 4 - 5 years. Each generation has a reproductive period and this influences whether generation refers to the shortest time for gene flow or the average time that genes operate in a commercial population. The size of this influence depends on the reproductive characteristics of each generation and the final size of the broiler chickens, but a basic pedigree unit consisting of 1 male and 10 females will produce around 50 million Broiler chickens or around 70,000 metric tons of Broiler chicken meat (Laughlin, 2007) .

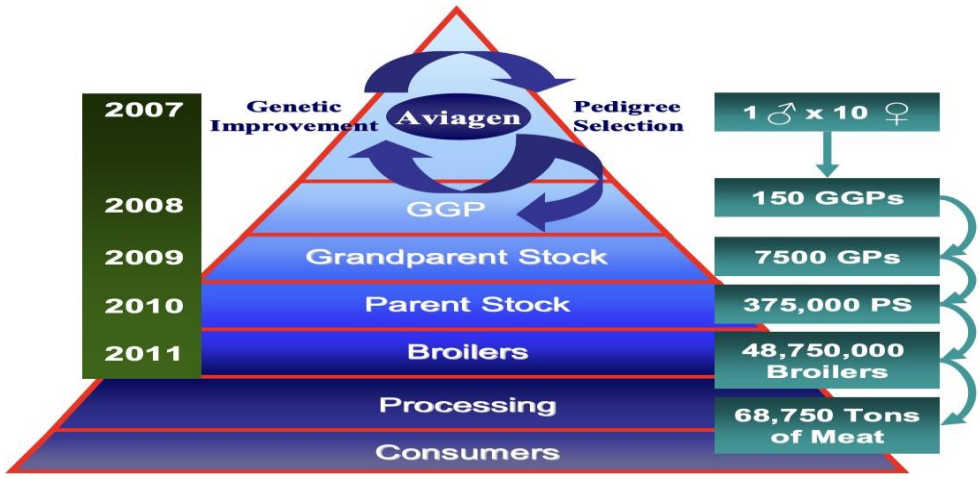

Fig. 1. Traditional description of a Breeding Programme applied to the Broiler Industry. **Source**: Laughlin (2007).

Pure line breeding for the development of special lines, i.e. male and female lines are developed through a unique selection program based on a different set of traits for male and female lines. Female lines are selected based on their reproductive performance, for example egg production, egg size, egg weight, shell quality, age of sexual maturity, and hatchability in addition to juvenile growth. Male lines are selected primarily to increase growth rate, body conformation, feed conversion ratio, and carcass quality (Saxena and Kolluri, 2018).

Commercial crossing is used in the poultry industry with the aim of maximizing efficiency as well as protecting genetic stock. Each strain carries separate traits to aid breeding efficiency, growth efficiency or yield and maximum carcass efficiency. A 4-way cross is obtained by crossing two male lines and two female lines

(Oleksandrivna, 2015). The four main lines used to produce modern broiler chickens are closed at the Pedigree and Great Grand Parent (GGP) level, with each line filling in any possible gaps in producing GGP. These GGPs were then crossed, to overcome further gaps, to produce parents for modern broiler chickens (Pollock, 1999; Siegel, 2014). When parent lines are crossed, the offspring have all the economically important traits a bird needs to produce meat or eggs efficiently. Additionally, 4-way crosses maximize heterosis. It takes between five and nine years to develop and introduce a new chicken breed to the market (Oleksandrivna, 2015).

Various cross breeds and genotypes have been used during the selection process to produce modern broiler genotypes, but currently the majority of commercial broiler chickens in the world are four-way crosses. The paternal GP (Grand Parent) is a synthetic line that is partly derived from White Comish. The maternal GP is also a synthetic line, based largely on the White Plymouth Rock (Crawford, 1990).

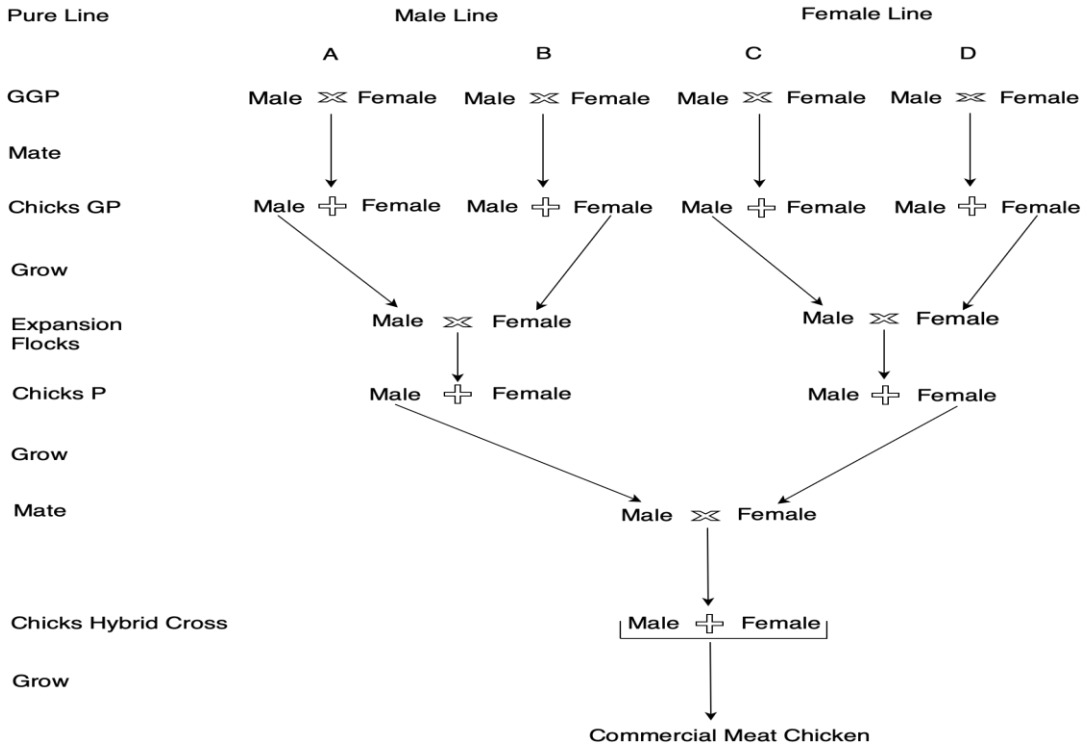

Fig. 2. Basic concept crossing in commercial poultry breeding. **Source**: Moreng and Avens (1989).

Usually the AB cross is considered the male, and the CD cross is considered the parent for the broiler, resulting in a four-way cross. One or more GGP and GP can be used to produce one of several types of modern broiler chickens (Pollock, 1999; Siegel, 2014).

III. BREEDING CONTRIBUTION TO ECONOMIC FACTOR

The commercial broiler industry began around 1935. Two large companies that have grown into today's leading commercial poultry breeders are Ross Breeders and Cobb Breeding Company. From 1935 to the present there has been genetic selection within and between breeds (industrial breeds e.g. White Cornish, Rhode Island Red) and genotypes (lines produced by various commercial companies e.g. Ross 308, Cobb 500). The main objective of this growth selection is to increase the profitability of broiler production in various related ways such as increasing lean muscle yield and increasing food utilization efficiency (Havesstein, 1994a,b). As a result, Zuidhof *et al*. (2014) showed that the growth rate of broiler chickens increased by more than 400% between 1950 and 2005, when chickens genetically representative of those years were placed in the same environment (Tellentire, *et al.*, 2016).

Fig. 3. Genetic selection and improved nutrition are the main reasons poultry producers are able to produce a much larger bird than they were 50 years ago. (Photo courtesy of G. B. Havenstein and P. R. Ferket, North Carolina State University.). **Source**: Zhai (2018).

Fig. 3 illustrates genetic selection in chickens. These two carcasses are the result of feeding and raising two different types of chickens under the same conditions. The chicken on the left is a strain known as ACRBC chicken. This strain has been raised at the University of Georgia and has not undergone genetic selection for growth rate since 1957. The carcass on the right is a popular broiler strain that was used by the industry in 2001. This strain has undergone genetic selection for approximately 45 years. Genetically selected chickens are about five times larger than strains that have not undergone genetic selection (Zhai, 2018). Breast section of a 1957 model broiler (left side) at 42 days old (0.59 kg) versus a 2001 model (right side) at 43 days old (2,905 kg). Most apparent differences result from genetic selection. However, improved nutrition and management also play a role in the efficiency of the poultry industry in producing meat today (Oleksandrivna, 2015). Carcass meat production, and especially breast meat production, is now a very important economic trait, whereas it was rarely considered in breeding programs 10 years ago. To some extent, geneticists must be able to predict future market trends, because in most pure line breeding programs, selection is carried out approximately 4-5 years before their offspring emerge as commercial broilers (Leeson and Summer, 2009). This can be illustrated by taking all the offspring from a pair of chickens and only raising the fastest growing chickens (or chickens with the most breast meat) to be used as breeding stock for the next generation, then continuing to do the same thing for 5 years (10 generations).), then you can get chickens that gain weight very quickly or have a lot of breast meat (Oleksandriva, 2015).

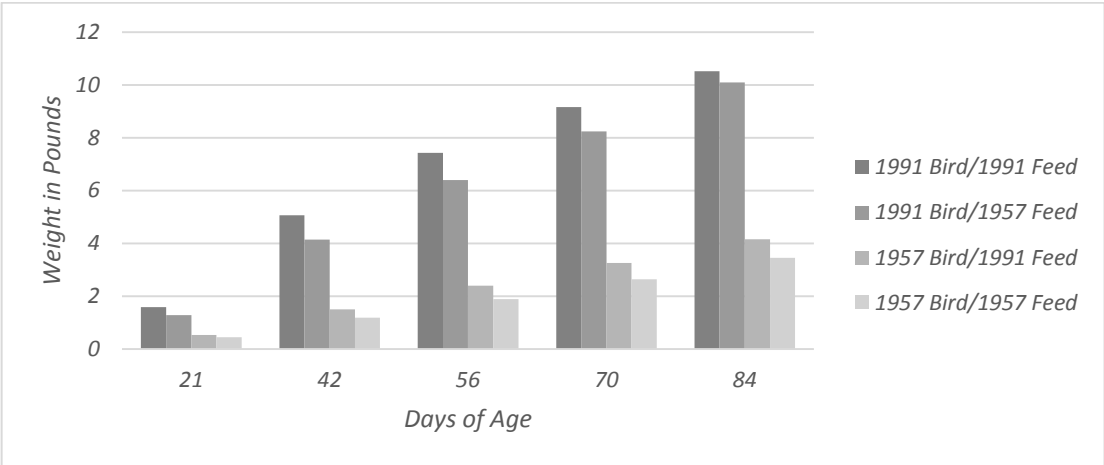

Fig 4. Improvement in Broiler weights in 1991 versus 1991. Source: Havenstein et al. (19994a).

Havenstein *et al.*'s research (1994a) conducted at North Carolina State University compared the performance of broiler strains used in 1957 with broiler strains used in 1991. Researchers fed each strain in 1957 or on feeds that are common today. Broilers are not given antibiotics and are not given hormones. The average body weights of these chickens are shown in Figure 4. Although feed slightly improved performance, 1991 chickens weighed more than 1957 chickens, regardless of feed. At eight weeks of age, the 1991 chicks weighed approximately 4 pounds more than the 1957 chicks. A comparison of the 1957 chicks with the 1991 chicks

provides an example of the genetic progress made in the poultry industry with respect to growth. In addition, modern poultry more efficiently converts feed into meat (Tabler, 2021). For certain factors, Leeson and Summer (2009) state that an increase in live weight of +0.18 kg at a certain market age will reduce overall costs by 14/kg live weight of broilers produced.

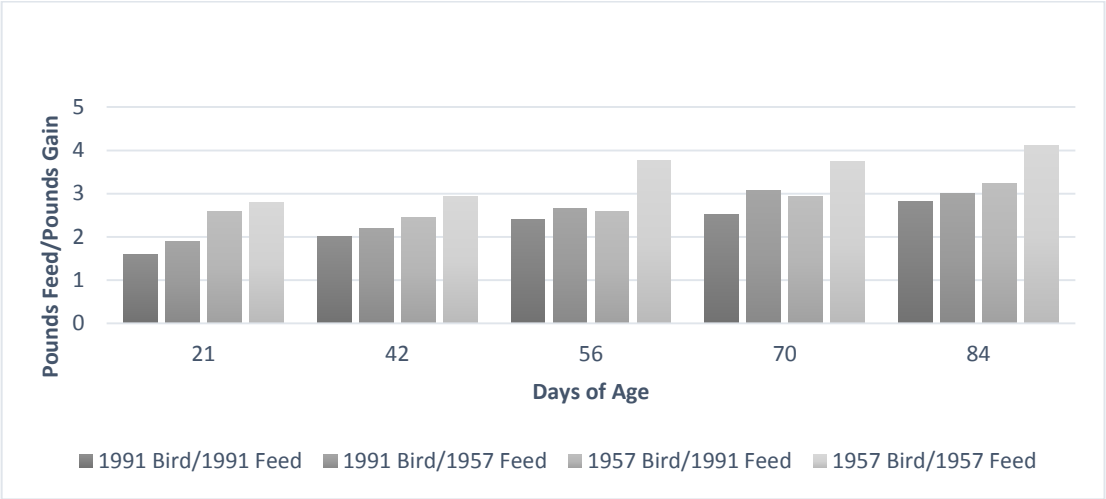

Fig 5. Improvement in Broiler feed efficiency in 1991 versus 1991. Source: Havenstein et al. (19994a).

Feed conversion data are shown in Fig. 5. The 1991 chickens were more efficient at converting feed into meat than the 1957 birds, despite the fact that the feed was much heavier. However, the news about fast-growing chicken breeds is not always good (Tabler, 2021). The drastic increase in the feed efficiency of chickens in a given year situation is due to genetic selection, the aim is to get a measure of how efficiently the feed is used by the chickens, which is clearly of economic importance as feed accounts for around 60 - 70% of the total production costs. Although nutritional requirements for the three strains may be different, genetic selection accounted for 85 to 90% of the increase in body weight from 1957 to 1991 (Havenstein *et al.*, 1994a; Hiemstra and Napel, 2013).

Growth is a complex physiological process of cell division that begins at fertilization and continues until reaching adult body weight. An individual's genetic code determines the beginning and end of developmental phases, although changes in environmental factors can influence that development. Neurological development occurs initially and is then followed by the formation of bone, muscle and adipose tissue (Marks, 1995).

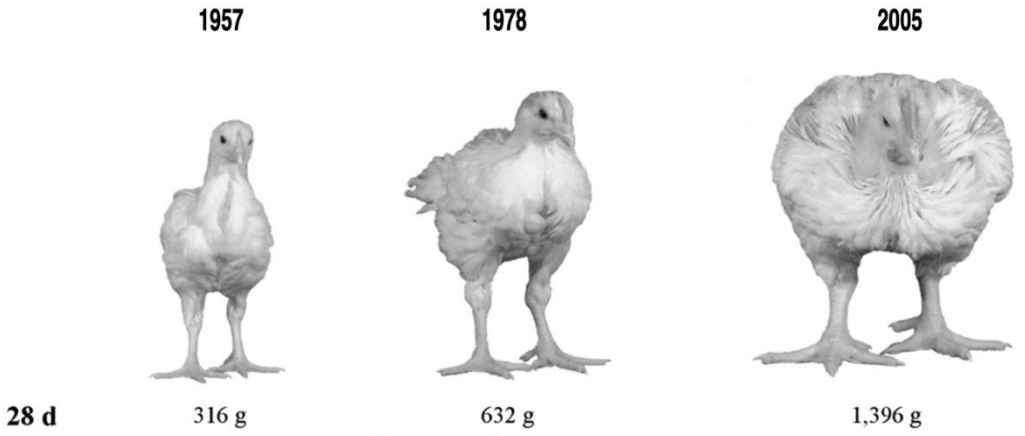

Figure 6. Age-related changes in size of University of Alberta Meat Control strains unselected since 1957 and 1978, and Ross 308 broilers (2005). Within each strain, images are of the same bird at 28 days old. Source : Zuidhof *et al.* (2014).

Images of the front view of chickens at 28 days of age as well as the average body weight and mixed sex for each strain in different years are presented in Figure 6. The AMC-1978 strain is a different strain from the other two strains. At 4 weeks of age, the relative body weight of the AMC-1978 strain reached its highest

point of around 43% of the body weight of the 2005 strain, and the relative body weight of the AMC-1957 strain reached its highest point of around 21% of the body weight of the 2005 strain (Zuiddhof *et al* ., 2014). Mitchell and Smith (1991) noted that selection for rapid growth rates produced animals with reduced relative amounts of mucosa in the small intestine, indicating increased efficiency of digestion and absorption per unit of mucosa. In addition, selection for rapid growth appears to have impaired satiety mechanisms in the hypothalamus leading to failure to reduce hunger drives and consequently leading to hyperphagia or overconsumption (Burkhart *et al.*, 1983; Dunnington and Siegel, 1996). Many factors have contributed to the large increase in Broiler size over the last 50 years, but hormones are not among them. Currently, no poultry producers use hormones; instead, they rely on good nutrition and rapid genetic selection to maximize growth. This means that they can meet the high demand for healthy protein sources at affordable prices for all (Siegel, 2014). Currently, selection objectives are being revisited to answer market demands in terms of welfare and disease resistance, in addition to the usual breeding objectives for yield and feed efficiency (Tixier-Boichard, *et al.*, 2011), genetic selection accounts for approximately 80% of performance improvements modern broiler chickens and nutrition only contribute 20% (Gavin, 2001).

IV. CONCLUSION

The success of the Broiler industry in terms of increasing growth rate (body weight) and yield efficiency has been discussed. Increased productivity has been achieved through intensive programmed selection of production traits over several generations in purebred populations as a crossing strategy in producing production animals. Improving these characteristics is necessary to accommodate economically, with the ever-increasing increase in feed costs, so that it is able to maintain its existence as a provider of cheap animal protein for the community and is sustainable with minimal environmental impact.

Genetic selection programs over the last 50 years have resulted in rapid growth rates and increased meat yields in Broiler chickens, drastic reductions in age at slaughter and the amount of feed required to raise these birds to market weight with growth increases of over 400%. This increase is caused by genetic selection and the rest is caused by nutrition and the environment.

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Fig. 1.1. Increase of efficiency of meat production in pigs and poultry over four decades calculated for the entire life of the animal from birth to slaughter.

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Breed ayam modern adalah hasil evolusi miliaran tahun melalui seleksi alam, yang mana seleksi buatan untuk tujuan komersial telah diterapkan. Sejauh ini, kemajuan terbesar dalam genetika ayam sejak domestikasinya terlihat pada paruh kedua abad ke-20, sejak munculnya pertanian skala industri (Schmidt dkk. 2009). Hal ini dapat dikaitkan dengan perkembangan genetika kuantitatif dan keberhasilan penerapan komersialnya (Siegel dan Dunnington 1997).
Metode pembibitan ayam pedaging dapat diringkas dalam langkah-langkah berikut: pada tingkat tertinggi, galur pembibitan murni dimiliki dan dikendalikan oleh perusahaan pembibitan. Jalur-jalur ini tunduk pada program seleksi skala penuh; dari jalur inilah seluruh produk ayam broiler suatu perusahaan berasal (Muir dan Aggrey 2003). Stok kakek buyut, yang dihasilkan dari galur murni, harus melalui seleksi massal untuk sifat-sifat yang dipilih. Tingkat pertumbuhan secara konsisten menjadi ciri seleksi utama sejak tahun 1950an, dengan penekanan

yang lebih baru pada hasil daging dada, kelayakan hidup dan efisiensi penggunaan pakan (Emmerson 1997; Muir dan Aggrey 2003; Laughlin 2007; Renema dkk. 2007). Galur kakek-nenek tertentu dikawinkan silang untuk menghasilkan induk, yang kemudian didistribusikan ke pedagang spesialis dan produsen terintegrasi. Langkah terakhir dari seleksi buatan intensif adalah persilangan hibrida (induk) untuk menghasilkan ayam pedaging produksi, yang dipelihara untuk disembelih oleh perusahaan produksi. Banyak kemajuan yang telah dicapai dalam teknologi seleksi buatan selama satu abad terakhir: mulai dari seleksi massal hingga penggunaan grafik silsilah dan hibridisasi, hingga pengenalan indeks seleksi dan inseminasi buatan, hingga pengembangan teknik estimasi nilai pemuliaan modern (Rishell 1997; Muir dan Aggrey 2003). Akibatnya, Zuidhof dkk. (2014) menunjukkan laju pertumbuhan ayam broiler meningkat lebih dari 400 % antara tahun 1950 dan 2005 (Gambar 1), ketika ayam yang secara genetik mewakili tahun-tahun tersebut ditanam di lingkungan yang sama. Konsekuensi dari perkembangan ini terhadap sifat-sifat ayam pedaging, dalam rangka meningkatkan laju pertumbuhan dan efisiensi penggunaan pakan, menjadi fokus tinjauan ini.

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History of Commercial Poultry Breeding

Perkembangan Ilmu Pengetahuan dan Struktur Pemuliaan Komersial

Genom dari stok ayam modern yang digunakan untuk produksi daging mengkonfirmasi peran besar dari ras ayam berat Asia dalam ayam broiler modern (9)

Guo, Y.; Ou, J.; Zan, Y.; Wang, Y.; Li, H.; Zhu, C.; Chen, K.; Zhou, X.; Hu, X.; Carlborg, Ö. Researching on the fine structure and admixture of the worldwide chicken population reveal connections between populations and important events in breeding history. *Evol. Appl.* **2021**, *15*, 553–564. [CrossRef]

Ayam pedaging modern berasal dari ras unggas Cornish, Leghorn, New Hampshire/Rhode Island Red dan Plymouth Rock, yang dikembangkan pada abad ke-19 di Eropa dan Amerika Utara [14,15].

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Pada abad ke-20, kemajuan besar dalam genetika kuantitatif dan penerapannya pada peternakan mendorong pengembangan organisasi dan kemajuan ilmiah dalam peternakan unggas.

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