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A feasibility study of industrial hemp on Virginia commercial poultry production

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A Feasibility Study of Industrial Hemp on Virginia Commercial Poultry Production

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by Aaron Patrick Sloss

Accepted by the faculty of the Department of Engineering, James Madison University, in partial fulfillment of the requirements for the Honors College.

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PUBLIC PRESENTATION

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Abstract

This project sought to characterize industrial hemp as a potential competitive agricultural commodity for the state of Virginia. Specifically, industrial hempseed was evaluated as a feedstock for the commercial broiler (meat-chickens) industry in Virginia.

Data were gathered to identify both the advantages and disadvantages of industrial hempseed as a nutritional resource for broilers. Key nutritional compositions were identified, quantified, and compared to several common feed ingredients, such as soybean, wheat, corn, and sorghum. Hempseed (whole seed) was found to have a considerably high amino acid content, protein, fiber, and metabolizable energy – making it an attractive alternative to conventional feedstuffs.

However, there are several challenges that exist for the introduction of whole hempseed to commercial poultry diets. It should be noted that, "hemp is currently not an allowable component of commercial feed for animals that produce food for humans, and is not defined as a feed ingredient by the [Association of American Feed Control Officials] AAFCO" [1]. This is due to the uncertainties of the pharmacological effects of cannabinoids in broilers (and therefore in humans by consumption). Further research must be conducted to understand the effects of cannabinoids, notably delta-9-tetrahydrocannabinol (THC) and cannabidiol (CBD), on broilers when present in their diets.

Section 1 – Introduction

Industrial hemp (*Cannabis Sativa L.)* is an herbaceous plant grown in many geographic locations around the globe. It is a member of the cannabis family, as is marijuana, but has low levels of delta-9-tetrahydrocannabinol (TCH) comparatively; industrial hemp typically has a THC composition of less than 0.3% by mass, while marijuana typically contains 5-20% [2]**.** Industrial hemp, along with other species of the *Cannabis Sativa* and *Cannabis Indica* were effectively outlawed in the United States in the 1930s as part of the war on drugs with the "Marihuana Tax Act of 1937" [3]**.** Industrial Hemp importation and domestic production became less viable due to these taxes, until it was listed on par with narcotics by the 1970s [3].

Within the past several years, there has been a wide-resurgence of interest towards industrial hemp grown in the United States [4]. This can be attributed to the vast variety of practical uses of the plant; this can include applications from fibrous material – clothing, rope, construction materials – in addition to oil and seed applications – food, fuel, body oil and lotions, etc. Currently, hemp-based products are imported from various international markets including Canada, China, and several countries in the European Union, among many others [5]. Although hemp-based products can be purchased in the United States, it is illegal to grow as a domestic crop. With the resurgence of interest across the US, hemp has been identified as a potentially valuable agricultural crop – considering its wide variety of applications in a many commercial industries.

Section 1.1 – Purpose Statement and Research Questions

This purpose of this research is to identify and discuss the implications of a Virginia-based hemp industry on Virginia commercial poultry production, specifically broilers. Industrial hemp and hemp-based feed products have the potential to be implemented into the agro-economical model of Virginia, yet they have been burdened by regulatory obstacles. Because of this, there is a considerable need for a developed research framework of such an industry, which includes a market evaluation, comparisons of hemp feed(s) to current industry standards, characterization of samples grown regionally to determine industry applicability, and a model for future pharmacological studies to study the direct effects of hempseed fed to poultry. Questions that this research seeks to explore include:

1) What specific areas of Virginia's agro-economic model is industrial hemp a viable commodity?
2) What is the chemical or nutritional composition of industrial hemp, specifically hempseed?
3) How does hempseed compare to other standard feed ingredients used in the commercial poultry industry?
4) What are the challenges and limitations associated with a hemp industry in Virginia?
5) What opportunities are there for future research with regard to industrial hemp in Virginia?

This project utilizes systematic, quantitative methods to characterize potential agricultural opportunities associated with industrial hemp in Virginia. Relevant data were gathered that quantifies industrial hempseed's nutritional value as well as standard nutritional requirements for broilers in the United States.

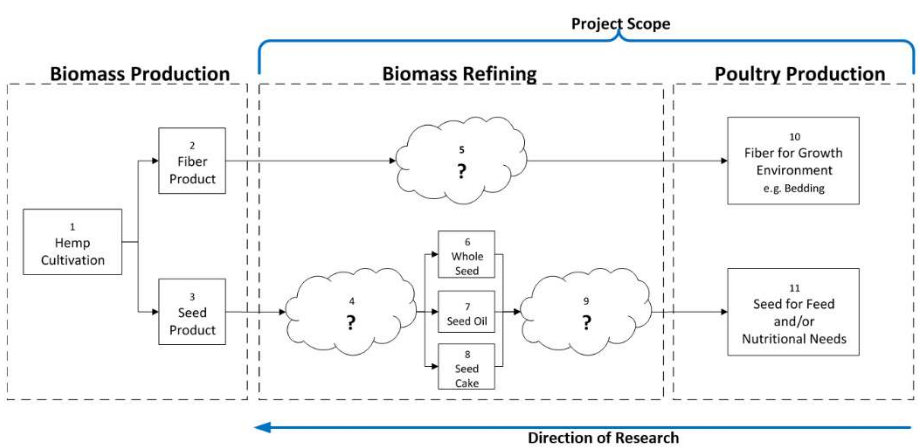


Figure 1 - Basic Research Structure

Section 2 – Literature Overview

This section provides a literature-based review of industrial hemp production methods in the United States, as well as a characterization of the Virginia commercial poultry industry. Additionally, broiler performance is discussed and opportunities for industrial hemp products (seed and fiber) to be integrated into the agro-economic model of Virginia are identified.

Section 2.1 – Industrial Hemp Production

Within the United States, many states including Virginia have proposed and passed laws (i.e. Va. Code § 3.2-4112 et seq.) that allow the planting, growing, and harvesting of industrial hemp for research purposes [6]. Specifically in Virginia, public universities such as James Madison University (JMU), Virginia Tech (VT), the University of Virginia (UVA), and Virginia State University (VSU) have participated in this research program in the past several years [6]. In 2018, approximately 135 acres of industrial hemp were planted in Virginia, with total acreage expected to increase over the next several years [6].

As mentioned, industrial hemp is typically planted with the intention of cultivating fibrous material or seed/oil material [7]. In order to produce fibrous material (the bast fiber from the stalk of the hemp plant), seeds are planted at a higher rate – typically 40-80 pounds of seed per acre, while hemp plants grown for its seed, flower, and oils are planted at a lower seed rate – typically 25-40 pounds of seed per acre [7]. Figure 2 represents crop densities

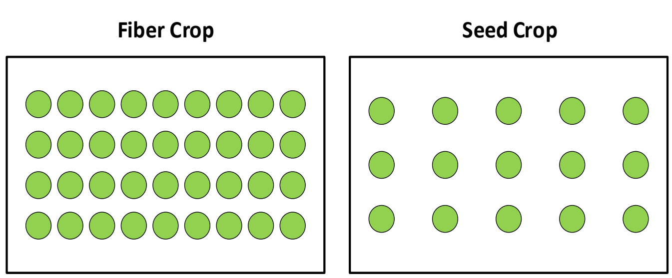


Figure 2 - Visualization of Crop Densities

Table 1 - Typical Planting Specifications of Industrial Hemp [8]

Planting Specifications			
Crop Type	Row Spacing	Seed Density (per acre)	Crop Density (per sq. ft.)
Seed Crop	6-7 in	25-40lb	10-15 plants
Fiber Crop	6-7 in	40-80lb	30-35 plants

of the two typical seeding rates. Seed rows are typically planted at the same distance for both cases.

With respect to seed and oil production, industrial hemp can potentially be characterized as a viable alternative to many current agricultural commodities, such as soybean, corn, wheat, and rape seed (to name a few). Specifically, hemp seed products – whole seed, seed meal (cake), and seed oil – can be seen as a valuable nutritional resource [8]. Industrial hempseed is particularly high in key nutritional components, such as dietary oil, fiber, and protein [8].

Section 2.2 – Introduction to Market

Considering that this project seeks to evaluate industrial hemp as a potentially competitive commodity in Virginia, it is important to identify key market opportunities for the industry. The following sections provide information of the Virginia agricultural industry as a whole, as well as specific opportunities within commercial poultry production.

As of 2016, Virginia's largest revenue-producing industry is that of agriculture, providing an annual economic impact of $70 billion and supporting over 334,000 jobs within the state [9]. Of this industry, the top agricultural commodities include broilers, cattle/calves, milk, and turkeys, with a combined turkey/chicken inventory of over 43 million as of 2012 [9, 10].

Table 2 - Virginia's Top Agricultural Commodities [5]

Virginia's Top Agricultural Commodities, 2016		
Rank	Commodity	Cash Receipts ($)
1	Broilers	733,000,000
2	Cattle/Calves	416,000,000
3	Milk	386,000,000
4	Turkeys	308,000,000

In 2018 alone, over 9 billion broiler chickens were produced in the United States, creating a wholesale value of industry shipments of $65 billion [11]. Additionally, there are more than 25,000 family farms in the US that produce approximately 95% of the nation's broiler inventory [11].

In order for a potential hemp industry to be included in Virginia's agro-economic model, several considerations must be made, of those being: 1) Virginia's capacity to grow hemp; 2) Climate influences on hemp growth; and 3) The available market share as an agricultural commodity.

Capacity to Grow Hemp

Currently, Virginia has approximately 44,800 farms with an average size of 181 acres [10]. Therefore, Virginia can be estimated to have over 8 million acres of farmed land. Some of Virginia's top farm crops include soybeans, corn, and wheat, which cover approximately 600k, 485k, and 230k acres as of 2018 [10]. It can be noted that in 2018, approximately 135 acres of industrial hemp were planted in Virginia [6]. As mentioned, this was made possible by the enacting of the Industrial Hemp Law which allowed the Virginia Department of Agricultural and Consumer Sciences (VDACS) to establish and oversee an industrial hemp research program in Virginia. Coupled with experiences with the research program (among the 4 universities and licensed associates) and land availability, it is feasible that Virginia can house a sizable industrial hemp production industry.

Climate Influences

Factors such as rainfall, available sunlight, soil composition, and even experience with the crop can affect planting regimens and crop success. Historically, industrial hemp has been grown in Virginia. An example of this can be seen at George Washington's Mount Vernon, where hemp was grown for various industrial uses [12]. It should be noted that industrial hemp was grown at all five farms that make up Mount Vernon (Union Farm, Mansion House, River Farm, Dogue Run Farm, and Muddy Hole Farm) [12].

As part of the industrial hemp research program(s), hemp has been grown to varying successes. Multiple cultivars were used in field studies, but vary widely in their ability to both outcompete pests and weeds [13]. It is important to mention that extreme weather (abnormally high rainfall) during the summer of 2018 impacted these field studies to the extent that a number of field sites failed to outcompete weeds (inhibiting hemp growth) [13]. Further study will help highlight the successes and challenges of growing hemp in Virginia, and its implications for a successful incorporation of seed product into the commercial poultry industry.

Available Market Share – A Comparison to Soybean

Virginia's largest crop (by planted acres) is soybean, with approximately 600,000 acres planted in 2018 [10]. Interestingly, over 63% of US soybean meal is used in commercial poultry production (turkeys, broilers, and layers) [14, see figure 4]. Specifically, Virginia poultry consumed a total of nearly 600 thousand tons of soybean meal (446.3 and 150.7 thousand tons fed to broilers and turkeys, respectively) in 2017; this places Virginia as the 16th largest consumer of soybean meal (including non-poultry production) [14]. Because of this, it is feasible that industrial hempseed could be a suitable partial replacement to soybean meal used in poultry feed.

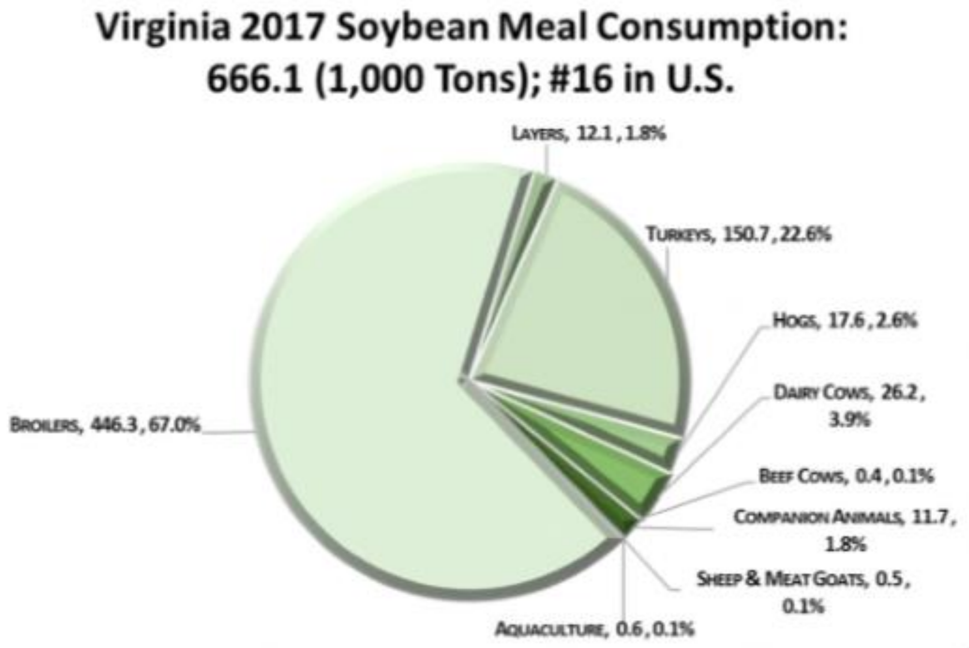


Figure 3 - Virginia Soybean Meal Consumption, By Sector [14]

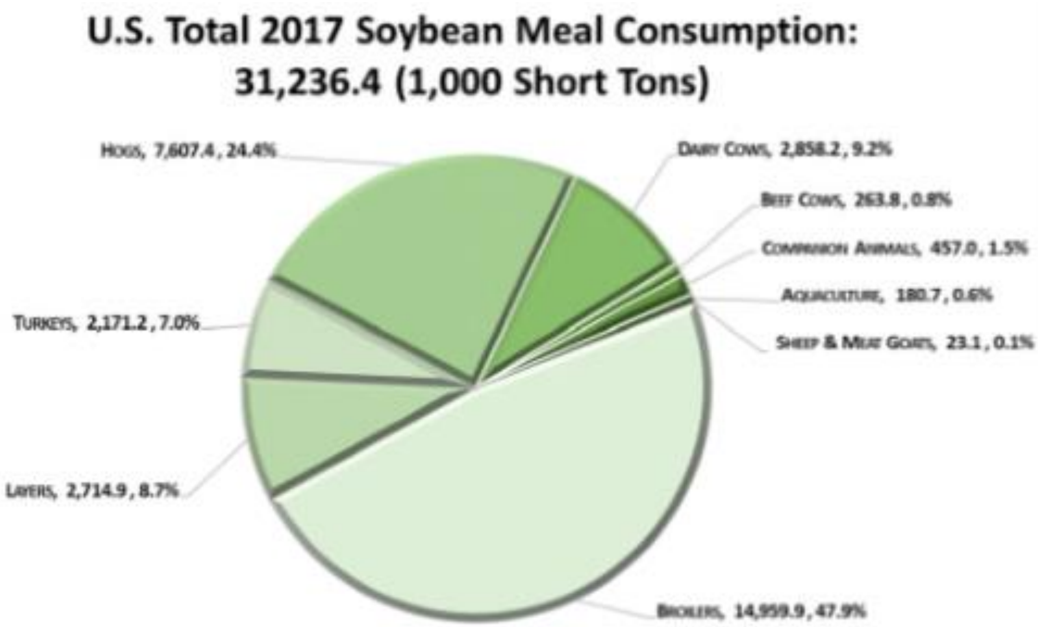


Figure 4 - Total US Soybean Meal Consumption, By Sector [14]

Other Considerations

In addition to the aforementioned factors that contribute to Virginia's ability to successfully integrate industrial hemp into the commercial poultry industry, other considerations must be made, those being [15]:

- Proximity of Feed Mills
- Proximity to Poultry Farms (including breeding farms & hatcheries)
- Transportation Services

Because hempseed would likely be incorporated into current diets, it is important that there be infrastructure to support augmentation with other feeds. If seed is to be processed into oil and seed cake, it must be done so at supporting facilities. Additionally, close proximity to farms can reduce the associated costs of feeding hempseed to broilers. An advantage of a Virginia-based industry is the existing structures in place to support a new feed. Considering the vast network of farms growing feed (corn, wheat, soybean, etc.), poultry farms, processing plants, etc., the incorporation of hempseed as an alternative feed is feasible.

These factors/considerations affecting Virginia's ability to grow hemp and bring seed to market are not all-inclusive. There still exists other challenges that can significantly affect the viability of a potential hemp industry in Virginia. However, due to the existing infrastructure of Virginia's agricultural industry, much of the work is already completed.

Section 2.3 – Broiler Production

In 2017, Virginia produced 277.4 million broilers, with average weight of 5.8 pounds, making Virginia #10 among the United States for quantity of broilers produced [16]. This equates to over 1.6 billion pounds of Virginia poultry produced in 2017 alone.

Broiler performance has improved significantly in the last century. For example, broiler weight at market has improved from approximately 2.5 pounds (in 1925) to over 6.2 pounds in 2018 – nearly a 250% increase [17]. Broiler age at market has decreased from 112 days to only 47 days over the past century, while mortality of these birds has decreased from 18% to approximately 5%. Most importantly – in relation to industrial hemp's marketability in this industry – the broiler feed to meat gain ratio (the amount of feed required to gain a proportional amount of meat) has decreased significantly. This ratio has decreased from 4.7 (lb_{feed} / lb_{meat}) to 1.82 in 2018 [17]. This can largely be attributed to optimization of poultry diets, genetic selection, and other key environmental factors such as temperature, humidity, bedding conditions, etc. [17]. Boiler performance for these specific parameters are shown in figures 2-5.

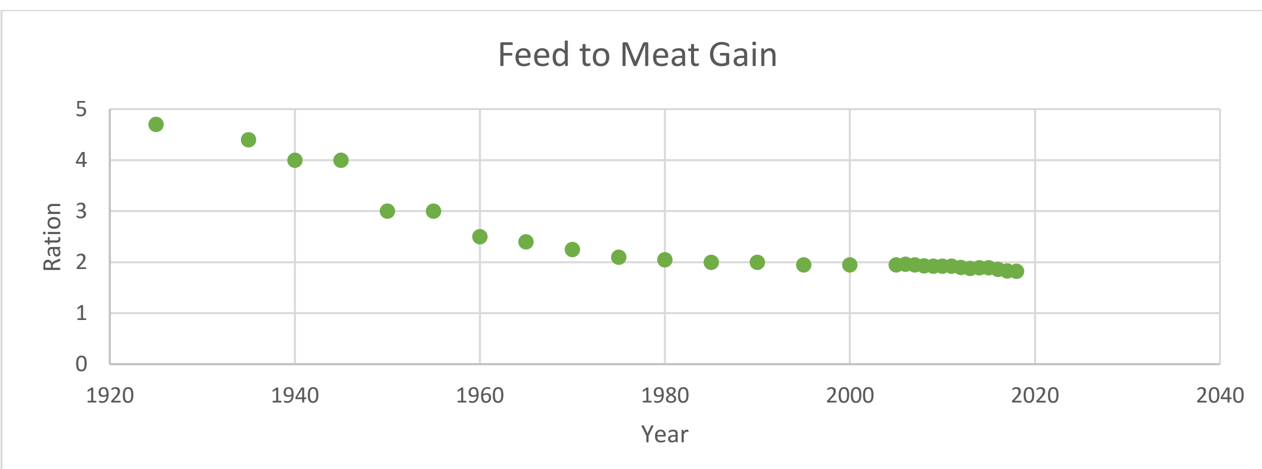


Figure 5 - Average Feed to Meat Gain Ratio of US Broilers [17]

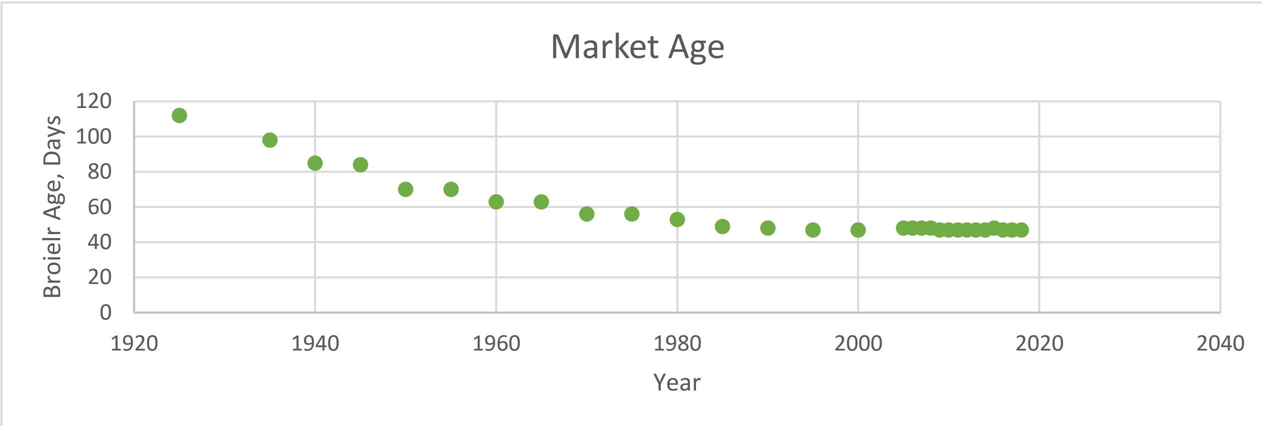


Figure 6 - Average Market Age of US Broilers, Days [17]

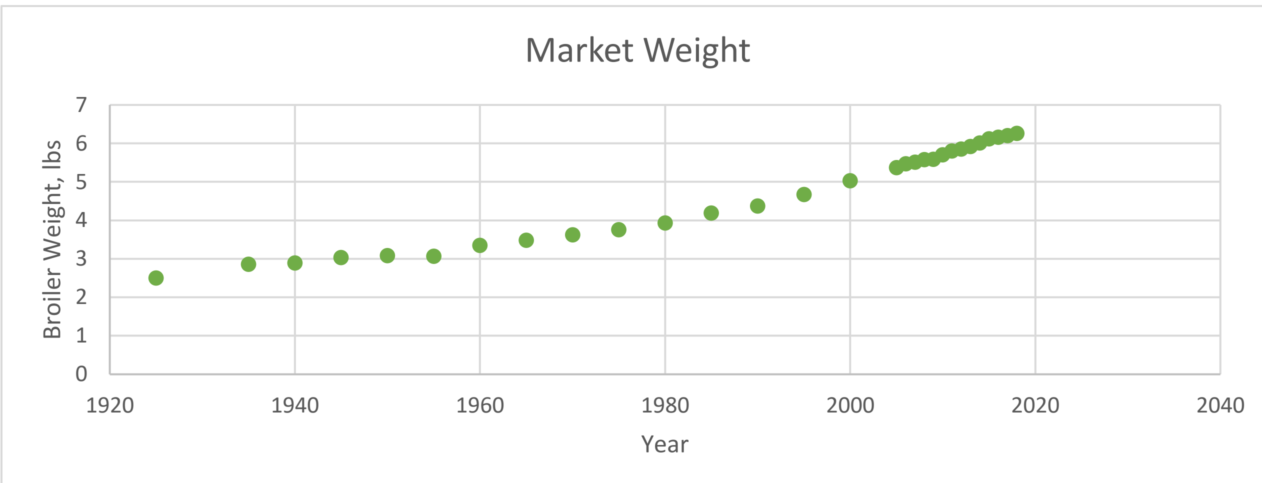


Figure 7 - Average Market Weight of US Broilers, Pounds [17]

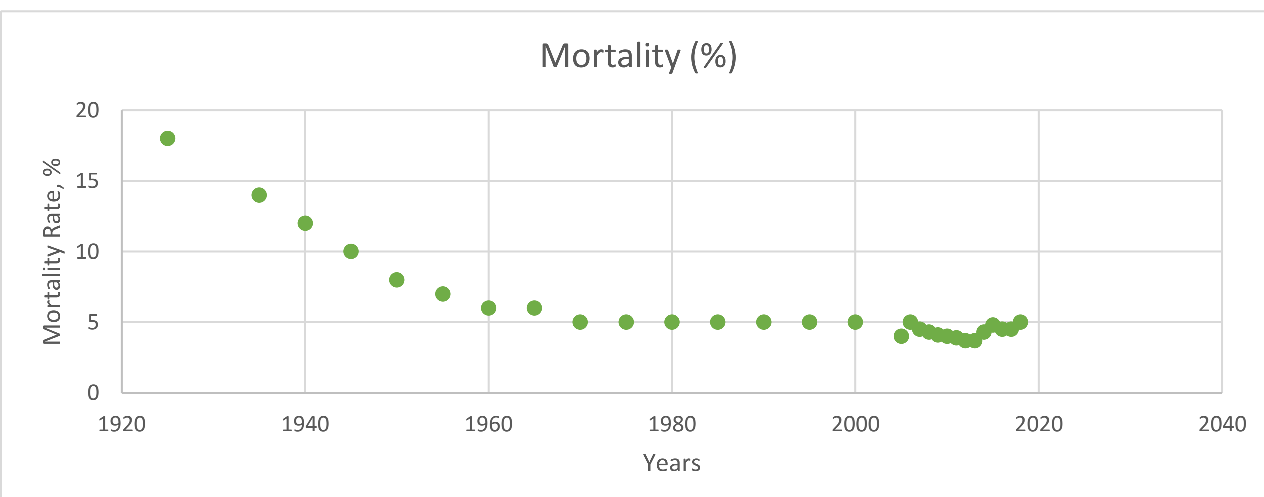


Figure 8 - Average Mortality Rate of US Broilers, % [17]

Section 2.3.1 – Broiler Nutritional Requirements

Broiler chickens (as well as other poultry birds, such as turkeys and layers) have several nutritional requirements that help ensure optimal growth and overall health [18]. The six basic nutritional components in any poultry diet include: Carbohydrates, fats, proteins, vitamins, minerals, and water. The importance of each nutritional component are summarized below. It is important to note that this information describes the poultry requirements of poultry in general – where a broiler's specific requirements are very similar.

Carbohydrates

Carbohydrates are a key source of energy for poultry. They are usually consumed by poultry in the form of starches and sugars; carbohydrates that are not typically digested by poultry are considered crude fiber [19]. The majority of carbohydrates are introduced to poultry diets in the form of cereal grains (wheat, corn, sorghum, etc.) [18].

Fats

Fats are another primary source of energy for poultry. Fats have roughly 2.25 times the amount of calories of carbohydrates by weight, and are a primary source of fatty acids - which are responsible for many bodily processes [19]. Fats (usually in the form of animal fats or vegetable/seed oils) provide linoleic acid, a required fatty acid among others. Linoleic acid is not generated from other nutrients by poultry, so it is important that this be included in the diets of broilers [19, 20]. Additionally, fats aid in the absorption of fat-soluble vitamins (ADEK) and help mitigate grain dust [19]. It is important to note that in poultry diets including fat, antioxidants are typically added as well to prevent the feed from going "rancid" [19].

Proteins

Proteins are comprised of long chains of amino acids (i.e. many polypeptide chains) that contribute to the construction of body tissues (and other structural component of broilers, particularly muscle) [18, 19]. The amino acids that makeup proteins in a diet can be divided into two separate categories: Essential and non-essential amino acids. Essential amino acids are supplied to poultry (broiler) feeds through a variety of feedstuffs, as no single can provide all eleven essential amino acids [19]. It should be noted that of the eleven essential amino acids, two are particularly important: lysine and methionine [19]. As Dr. Jacquie Jacob of the University of Kentucky notes, “Deficiencies of either of these will lead to a significant drop in productivity and the health of the flock” [19].

Vitamins & Minerals

Vitamins are organic compounds that are essential for many body functions, including healthy growth and reproduction [18]. Although they are only required in small amounts relative to other nutritional components, they are important in poultry diets. Vitamins can be broken down into fat-soluble and water-soluble; fat-soluble vitamins include ADEK vitamins, while water-soluble vitamins include B and C vitamins [19, 20]. C vitamins are generated by broilers themselves, and need not be directly added into their diets [19].

Minerals are inorganic compounds that are also essential for many body functions. Minerals can be classified as macro-minerals (high levels included in diet) and micro-minerals (low levels included in diet), and are important in poultry diets [20]. Macro-minerals include calcium and phosphorus, while micro-minerals include copper, zinc, magnesium, iron, etc. [20]. Additionally, salt (sodium, chloride) are included in broiler diets [20].

Water

Water is a critical nutritional component. Water helps regulate most bodily processes and poultry cannot survive (like other animals) long without it [19]. It is typical of broilers (and poultry in general) to consume approximately twice the amount of water as feed, by mass [19].

Nutrient requirements (both high and low nutrient diet varieties) for broilers is shown below in table 2.

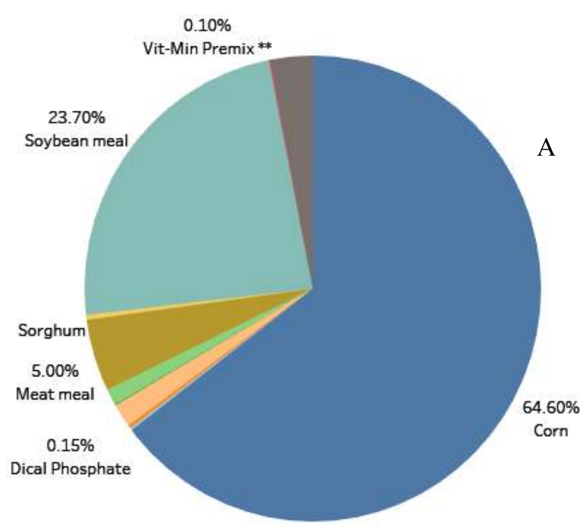
Table 3 - Nutrient Requirements for Broilers [21]

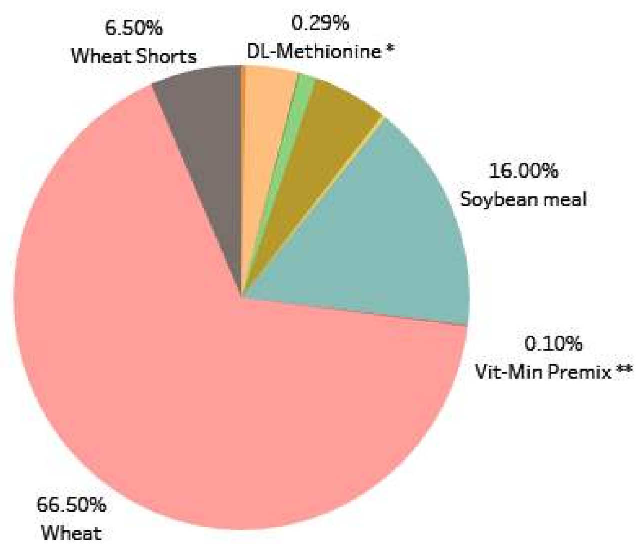
	Low Nutrient Density Diet Specifications for Broilers				**High Nutrient Density Diet Specifications for Broilers**			
Approximate Age	0-18d Starter	19-30d Grower	31-41d Finisher	42d+ Withdrawal	0-18d Starter	19-30d Grower	31-41d Finisher	42d+ Withdrawal
Crude Protein (%)	21	19	17	15	22	20	18	16
Metabolizable Energy (kcal/kg)	2850	2900	2950	3000	3050	3100	3150	3200
Calcium (%)	0.95	0.9	0.85	0.8	0.95	0.92	0.89	0.85
Available Phosphorus (%)	0.45	0.41	0.36	0.34	0.45	0.41	0.38	0.36
Sodium (%)	0.22	0.21	0.19	0.18	0.22	0.21	0.2	0.2
Methionine (%)	0.45	0.4	0.35	0.32	0.5	0.44	0.38	0.36
Methionine + Cystine (%)	0.9	0.81	0.72	0.7	0.95	0.88	0.75	0.72
Lysine (%)	1.2	1.08	0.95	0.92	1.3	1.15	1	0.95
Theronine (%)	0.68	0.6	0.5	0.48	0.72	0.62	0.55	0.5
Tryptophan (%)	0.21	0.19	0.17	0.14	0.22	0.2	0.18	0.16
Arginine (%)	1.3	1.15	1	0.95	1.4	1.25	1.1	1
Valine (%)	0.78	0.64	0.52	0.48	0.85	0.66	0.56	0.5
Leucine (%)	1.2	0.9	0.8	0.75	1.4	1.1	0.9	0.8
Isoleucine (%)	0.68	0.6	0.5	0.42	0.75	0.65	0.55	0.45
Histidine (%)	0.37	0.28	0.25	0.21	0.4	0.32	0.28	0.24
Phenylalanine (%)	0.7	0.65	0.55	0.46	0.75	0.68	0.6	0.5
Vitamins (per kg of diet)	100%	80%	70%	50%	100%	80%	70%	50%
Vitamin A (I.U)	8000				8000			
Vitamin D3 (I.U)	35000				35000			
Vitamin E (I.U)	50				50			
Vitamin K (I.U)	3				3			
Thiamin (mg)	4				4			
Riboflavin (mg)	5				5			
Pyridoxine (mg)	4				4			
Pantothenic acid (mg)	14				14			
Folic acid (mg)	1				1			
Biotin (µg)	100				100			
Niacin (mg)	40				40			
Choline (mg)	400				400			
Vitamin B12 (µg)	12				12			
Trace Minerals (per kg of diet)	100%	80%	70%	50%	100%	80%	70%	50%
Manganese (mg)	70				70			
Iron (mg)	20				20			
Copper (mg)	8				8			
Zinc (mg)	70				70			
Iodine (mg)	0.5				0.5			
Selenium (mg)	0.3				0.3			

Leeson, S., & Summers, J.D. (2009) *Commercial Poultry Nutrition* [19]

Section 2.3.2 – Broiler Feed Composition

In order to meet and/or exceed the recommended nutrient requirements, broilers are fed specifically formulated feed. Typically, feeds are composed primarily of a base feed – usually corn, wheat, or sorghum [21]. It is important to note that soybean meal is present in most commercial broiler diets, due to its nutritional composition (most notably, proteins). Industrial hempseed has the potential to augment current broiler diets as a partial replacement to soybean meal, as hempseed is a comparable feed with respect to key nutritional components. Sample diets (upon research, most commercial diets are proprietary) are shown below in 9A – 9C.





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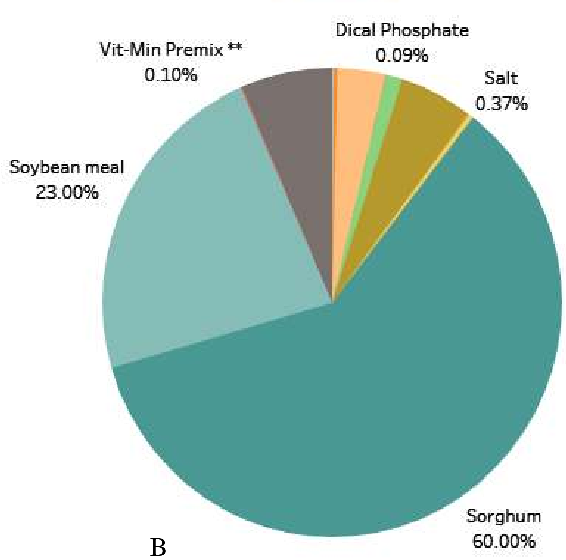

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Figure 9 - Alternative Commercial Poultry Diets; Typical Compositions [21]

Figure 9A – Corn Based Broiler Diet
Figure 9B – Sorghum Based Broiler Diet
Figure 9C – Wheat Based Broiler Diet

Section 3 – Characterizing Hempseed

In order to evaluate industrial hempseed as a viable alternative feed for commercial poultry, several key nutritional components were quantified. Those components include the eleven essential fatty acids (methionine and lysine, separated), metabolizable energy, crude fiber, and linoleic acid. The nutritional components quantified and compared are not all-inclusive; these results highlight the performance of hempseed in only a few (of many) nutritional parameters. However, those components analyzed can be considered to be the key building blocks of a broilers diet. Hempseed (whole) is compared to standard feed ingredients, including sorghum, soybean meal (48% crude protein), wheat, wheat shorts, and yellow corn. Results of these comparisons are shown in figures 10 – 14.

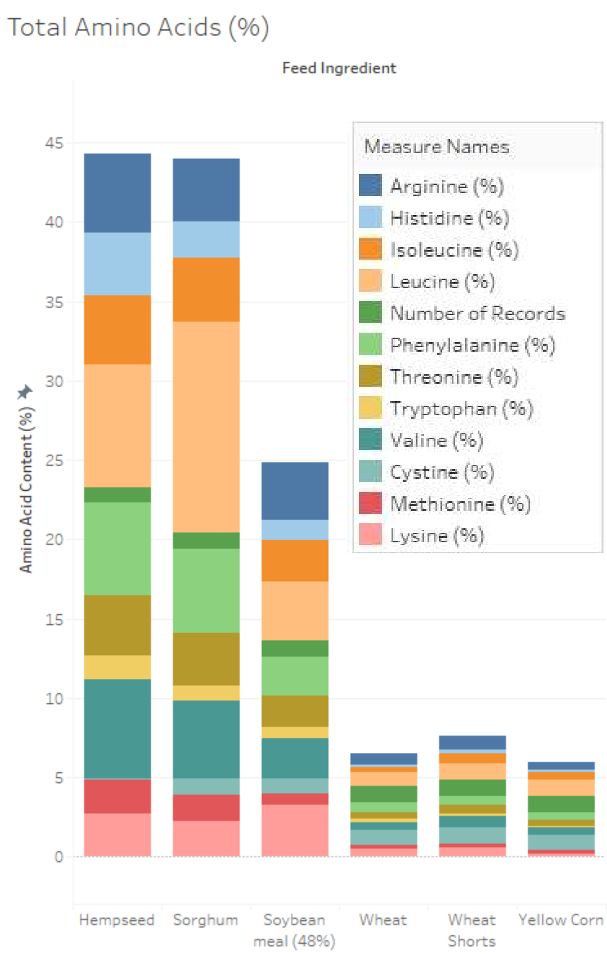

Figure 10 - Total Amino Acid Content (11 essential), [21,22]

Figure 10 shows the amino acid compositions of common feed ingredients in commercial broiler diets [21, 22]. It is apparent that whole hempseed has a high total amino acid composition (sum of all eleven essential amino acids) as compared so several other feeds. Comparing to soybean, hempseed has nearly twice the amount of total amino acids (essential), and therefore requires less total biomass added to commercial broiler diets to meet the same nutritional standards.

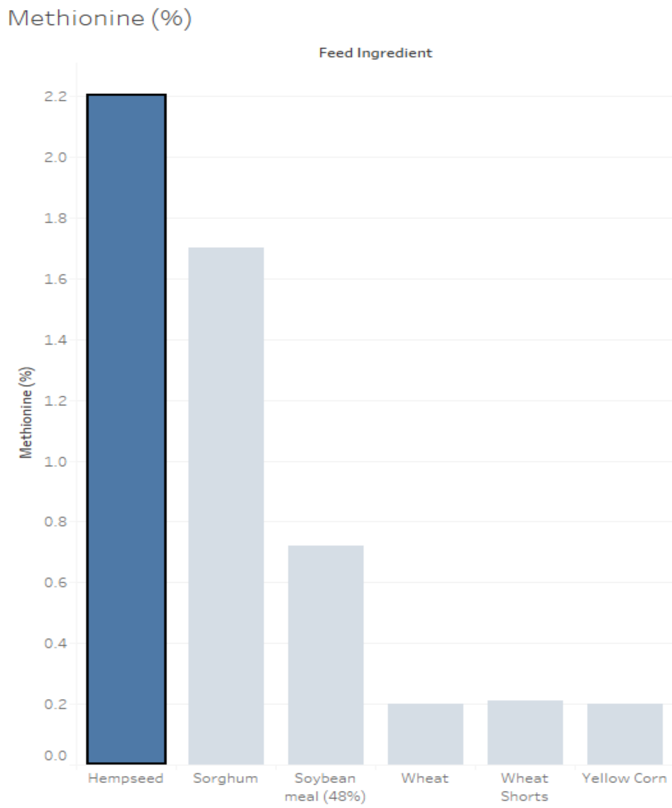

Figure 11 - Methionine (%) Content Among Common Feeds [21,22]

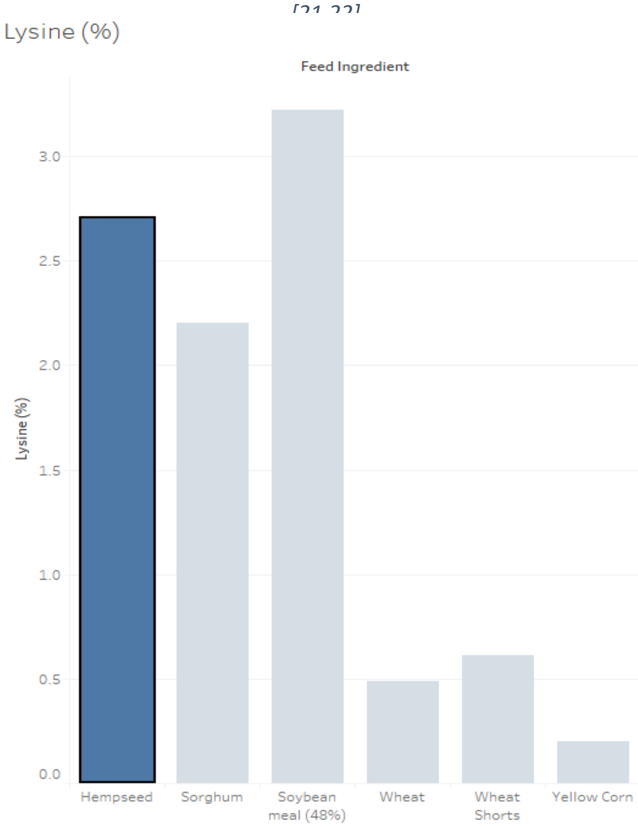

Figure 12 - Lysine (%) Content Among Feeds [21,22]

Notably, whole hempseed also has relatively high amounts of methionine and lysine, which have been cited as critical to broiler growth and overall health [19].

Industrial Hempseed has a value of methionine of nearly 2.2%, while the closest common feed is sorghum with approximately 1.7%. Besides sorghum, the remaining common base feeds (yellow corn and wheat) have a fairly low methionine content relative to the other feed types.

Additionally, the lysine content in hempseed is significant (at approximately 2.7%). Although this is not the highest value amongst the compared feeds, it can still be seen as a strong source of lysine. Since soybean provides the most lysine (% by mass), augmenting feed with both soybean and hempseed could be a viable option.

As shown in figure 13, the crude fiber content of industrial hempseed is

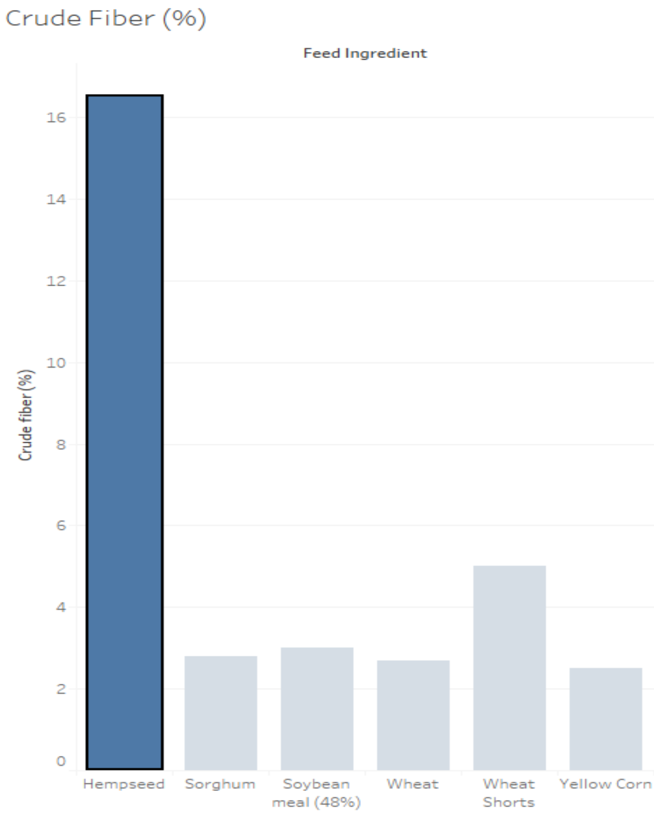

Figure 13 - Crude Fiber (%) Among Common Feeds [21,22]

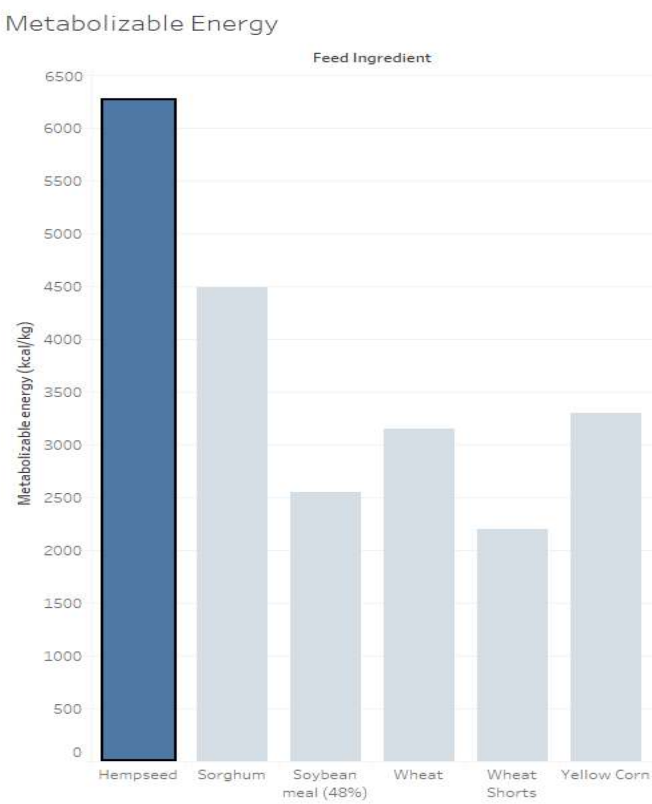

Figure 14 - Metabolizable Energy (kcal/kg) Among Common Feeds [21,22]

significantly higher than the other standard feeds (well above 300% more crude fiber than all other feed types).

The metabolizable energy of hempseed is also high relative to other compared feeds (see figure 14). A high amount of metabolizable energy is beneficial; "energy" is the most expensive nutrient and is an important factor in feed formulation, as it typically governs feed intake [20].

A high energy feedstuff allows for a low-feed intake. This is beneficial as it reduces the total mass of the feed consumed by broilers (and related costs associated with the processing and transport of the feed).

Linoleic acid (fatty-acid) is also particularly high; hemp seed oil can contain up to 56% linoleic acid; Soy has a comparable value of 55% [8].

Section 4 – Discussion of Results and Future Implications

The purpose of this research was to characterize industrial hemp, specifically hempseed, as a potentially competitive agricultural commodity in the state of Virginia. The data gathered to compare hempseed (whole seed) with several other common feed ingredients used in commercial broiler diet suggests that it can be a viable alternative feedstuff. It is especially high in protein, more specifically the eleven essential amino acids. Of those, two amino acids are especially important in the diets of broilers: methionine and lysine [19]. Hempseed has high relative amounts of these two compounds, which is beneficial for broiler growth and overall health.

Additionally, hempseed is very high crude fiber and metabolizable energy. High metabolizable energy (caloric content) can help reduce the amount of feed necessary to achieve the required nutrient intake of a broiler – in addition to other animal agriculture commodities. The results show that industrial hempseed is a promising source of key nutrients that could potentially help continue to improve broiler feed to meat ratios, increase market weight, and decrease market age of Virginia's top agricultural commodity.

Section 4.1 – Challenges and Limitations

This study characterized the nutritional composition (and competitiveness) of industrial hempseed. However, this data is limited to whole-seed, and does not delineate between seed products – seed cake (meal) or seed oil. In order to make an industrial hemp market viable in the agro-economic model of Virginia, it is likely that hemp seed would have to be processed for each constituent.

Another challenge to industrial hemp in Virginia is the presence of cannabinoids in hemp products, namely TCH and CBD present certain regulatory obstacles. As mentioned previously, “hemp is currently not an allowable component of commercial feed for animals that produce food for humans, and is not defined as a feed ingredient by the [Association of American Feed Control Officials] AAFCO” [1]. In order to begin to overcome these obstacles, Virginia-grown hemp samples must be analyzed for their chemical compositions. Although the presence of THC in industrial hemp is relatively low compared to that of marijuana, it nevertheless is a component of concern when feeding to poultry intended for human consumption. Further work to identify and evaluate the causal relationship of cannabinoid content of hempseed and effects on broilers must be completed.

Section 4.2 – Future Work

The chemical characterization of hemp samples is a key research goal as it provides insight into the required chemical processes that must be undertaken by a commercial hemp industry, provided that safety and regulatory burdens remain a hindrance to direct implementation into poultry feed. Each method used will provide researchers key data (original to regionally grown biomass) of hemp’s quality as an agricultural commodity.

Section 4.2 - A Framework for Characterization of Virginia Hemp Biomass

Potential methods that may be used to evaluate Virginia-grown hemp are summarized in Table 4. Furthermore, discussion is provided for an expected method to analyze cannabinoid content in pressed hempseed oil.

Table 4 - Proposed Analytical Methods for the Characterization of Virginia-Grown Hemp

Method	**Source**	**Title**
A	NREL	Determination of Extractives in Biomass
B	NREL	Preparation of Samples for Compositional Analysis
C	NREL	Determination of Structural Carbohydrates and Lignin in Biomass
D	Perkin Elmer	Determination of Cannabinoids in Hemp Seed Oils by HPLC Using PDA Detection
E	USSEC	Determination of Crude Fiber
F	USSEC	Determination of Starches, as well as non-starch Polysaccharides and Monosaccharides
G	USSEC	Determination of Fatty-acid profile
H	USSEC	Determination of anti-nutritional factors
I	USSEC	Data statistics and quality indicators

Determination of Cannabinoids in Hemp Seed Oils (HPLC) [20]

This method is for the determination of the concentrations of various cannabinoids that are present in hempseed oil (cannabigerol, cannabidiol, delta-9-tetrahydocannabinolic acid, etc.). To do this: (1) sample seeds are collected; (2) seeds are processed using a seed press to remove seed oil for analysis; (3) oil samples are diluted in isopropyl alcohol to reduce viscosity; (4) sample is analyzed using high-performance liquid chromatography (HPLC), and; (5) sample results are compared to a set of standards to determine constituent concentrations [23]

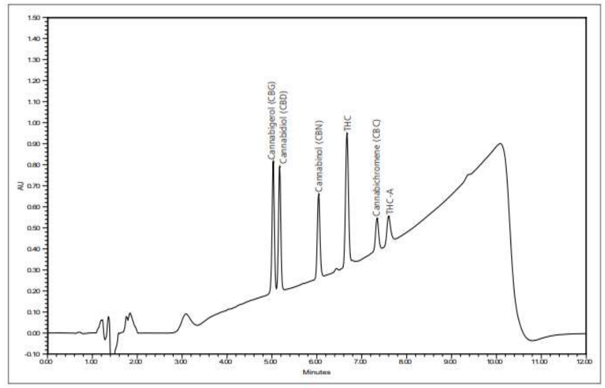

Figure 15 - Expected Graph from Qualitative HPLC Analysis [23]

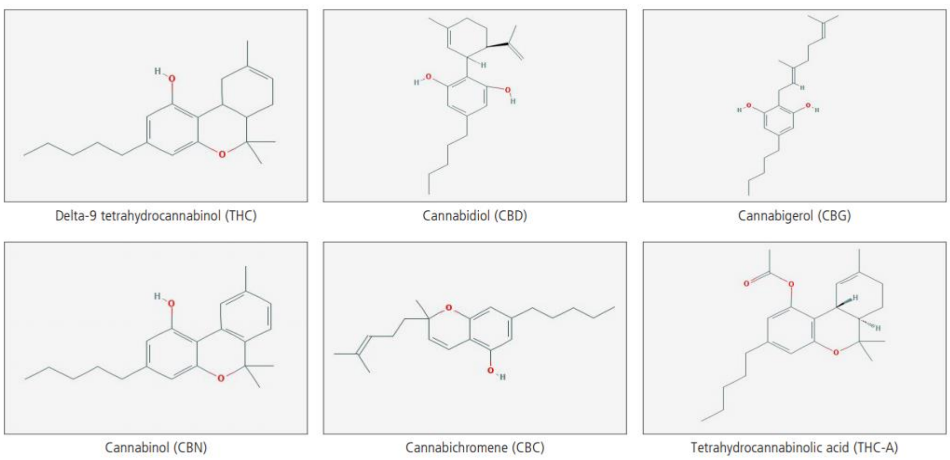

Figure 6 – Chemical Structures of Selected Cannabinoids [23]

It is important to note that the prescribed method above is for the determination of cannabinoids in hempseed oils; modifications will be made to conduct similar chromatography-based analysis of a variety of plant components. For example, step (2) may be replaced by other means such as a hexane-based extraction (Soxhlet) on ground stem-samples, effectively determining cannabinoid contents in the stem instead of the seed.

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