Review Article

BREWERS' DRIED GRAINS AS AN UNCONVENTIONAL FEED INGREDIENT IN BROILER RATION: A REVIEW

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ABSTRACT

Rising feed costs and competition for conventional feed ingredients such as maize and soybean meal have intensified the search for economical, and sustainable alternatives in poultry nutrition. Brewery waste, particularly brewers' dried grains (BDG), has gained attention as a promising unconventional feed resource rich in crude protein, fermentable fibre, B-complex vitamins, and minerals such as phosphorus. A critical appraisal of existing studies indicates that BDG can partially replace conventional feed ingredients without adversely affecting growth performance, feed conversion ratio, carcass yield, or haematological and biochemical indices of broilers, provided inclusion levels remain within optimal limits. However, high fibre content, variability in nutrient composition, and susceptibility to microbial contamination constrain its wider adoption. Enzyme supplementation, proper drying, and blending with energy-rich ingredients can improve its digestibility and nutrient balance. Economic analysis consistently demonstrate reduced feed costs and improved profit margins with BDG inclusion, underscoring its potential for cost-effective and environmentally sound poultry production. Further research is warranted to standardize processing techniques, optimize inclusion levels, and ensure product safety and consistency across brewery waste sources.

Keywords: Broiler, brewers' dried grains, carcass traits, performance

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INTRODUCTION

Poultry Industry in the World and India

Poultry is a prominent part of livestock farming. The poultry industry is growing rapidly to meet the increasing demand for high-quality protein in the form of meat and eggs. For educated unemployed individuals and various farming communities in developing nations, poultry farming has emerged as an important agribusiness enterprise with great potential to provide additional income (Ugwuoke *et al.*, 2017). Chickens are in high demand worldwide because they are hardy creatures that grow relatively fast. Chicken meat and eggs are among the primary sources of protein for many people globally, as evident in the production of 26.56 billion chickens

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in 2022, up from approximately 13.9 billion in 2000 (USDA-FAS, 2018). Moreover, global broiler meat production amounted to about 103.5 million metric tons in 2023 and is projected to increase to approximately 104.2 million metric tons by 2024.

According to the last Livestock Census in 2019, poultry production in India witnessed a 16.81% increase compared to the previous census, reaching a total poultry population of 851.81 million. Notably, the most significant growth occurred in backyard poultry, which saw a 45.78% increase, reaching a population of 317.07 million. However, commercial poultry production grew at a slower rate of 4.5%, with a total population of 534.7 million during the same period (DAHD, 2019). In 2022-23, India produced 138.38 billion eggs, with 118.16 billion from commercial poultry and 20.20 billion from backyard poultry. This marks a 33.31% increase from 2018-19 and a 6.77% increase from 2021-22 (Kumar *et al*., 2024).

In 2022-23, India produced approximately five million metric tons of poultry meat, accounting for around 51% of the country's total meat production. The broiler meat sector is currently experiencing an annual growth rate of 4.52% (BAHS, 2023). Commercial broilers contribute approximately 80-85% of the total poultry meat production, while backyard poultry accounts for the remaining 15-20%.

Unconventional Feed Ingredients

The scarcity of poultry feed in the country due to the high level of competition between humans and livestock for available feed ingredients is a major problem, leading to a lower-than-expected output from poultry. Moreover, the traditional sources of vitamins and proteins used in poultry rations—such as fish meal, meat and bone meal, soybean meal, and groundnut cake—are becoming increasingly expensive in developed countries (Gondwe *et al*., 1999). The availability of these ingredients is also inadequate due to the rising cost of raw materials.

Additionally, feed alone accounts for 70–80% of recurrent production inputs in intensive monogastric animal production, making the search for alternative feed ingredients essential (Ravindran and Blair, 1992; Fasuyi, 2005). The utilization of alternative feed ingredients in poultry rations is a key determinant of successful poultry production. The use of industrial by-products in monogastric animal nutrition provides a valuable means of indirectly producing animal protein and food from industrial waste products (El Boushy and Van der Poel, 2000).

Furthermore, it is predicted that global meat production will increase by 66%, while meat production in developed countries will grow by 78% by 2050 (IFPRI, 2018). Therefore, the search for alternative protein sources has become an urgent necessity.

Brewery Waste and Brewers' Dried Grains

Among the non-conventional feedstuffs that could be used in poultry ration formulation are brewery by-products.

Brewery by-products like brewers' dried grains (BDGs) and yeast are considered potential non-conventional feeds (Munthali *et al*., 1989a; Munthali *et al*., 1989b). The brewers' dried grains are obtained from barley, wheat, maize, rice and oat (Figure 1) It contains the insoluble materials remaining after the process of soaking, mashing and boiling with water (Areghore and Abdulrazak, 2005; Khalili *et al*., 2011; McCarthy *et al*., 2013; Radzik-Rant *et al*., 2018). Fermented local and industrial by-products of brewing have been utilized as non-conventional feedstuffs in broiler rations (Flores-Caballero and Avilla-Gonzalez, 1993), mainly as protein and energy supplements (Samanta and Mandal, 1988). These by-products serve as valuable sources of crude protein (CP), metabolizable energy (ME), and many B-vitamins (Vasso and Russ, 2007). Additionally, they are rich in phosphorus (P) but relatively low in calcium (Ca).

In this context, Parra and Escobar (1985) reported that 35 to 45 kg of dry matter (DM) can be obtained from the residues produced during the brewing of 1000 L of beer. Currently, a small proportion of this by-product is used as dairy cattle feed, while large quantities accumulate at production sites, leading to disposal and public health concerns. Despite its potential, this significant by-product has not been extensively utilized as a poultry feed source.

The purpose of this review was to collect all studies to provide a basis for future research and to highlight the nutritional value of BDG as a non-traditional feedstuff in broiler diets. The paper pivots on the brewery waste utilisation for broiler diet focussing on various characteristics like feed utilisation, performance, carcass and economic profile. The literature search was done with the help of two online databases (Google Scholar and ScienceDirect) using key words and evaluating article relevance. Articles were selected by the method of inclusion and exclusion based on the abstract.

Constraints

The incorporation of brewery by-products as poultry feed presents challenges concerning their (anti-)nutritional value, physical and sensory characteristics, and the risk of contamination in animal feed as depicted in Table 1.

The risk of disease is a major downside of feeding unconventional feedstuffs to some monogastric animals such as poultry. Additionally, the use of BDGs in poultry diets has some constraints, such as high moisture and fiber content. The high moisture content of wet brewers' grains (approximately 80%) increases their bulkiness. Therefore, efficient sun-drying is recommended to prevent nutrient losses in this by-product. Due to its high fiber content, BDG is primarily used as cattle feed. Since BDG is rich in fiber, the addition of fiber-degrading enzymes may enhance its feed value. However, numerous studies have explored the use of BDG in poultry diets.

Optimizing BDG for Animal Feed

Incorporating Brewers' Dried

Grains (BDG) into animal feed can be a cost-effective strategy, but it also presents certain challenges. Fortunately, there are practical solutions to enhance its nutritional value and overall efficiency. One approach is adding fibre-degrading enzymes to the feed. BDG is high in fibre, which can be tough for animals to digest. By including enzymes like cellulases and xylanases, we can help break down those complex fibres, making the nutrients more accessible. This not only boosts digestion but also ensures the animals get the most out of their feed (Adeyemi and Olorunsanya, 2020).

Another smart move is using BDG as a partial replacement rather than the main ingredient. While BDG is a valuable feed component, relying too much on it can create nutrient imbalances, especially when it comes to protein and energy content. Mixing it with other feed ingredients in the right proportions ensures animals get a well-balanced diet without compromising performance (Smith *et al*., 2021).

Proper drying and storage techniques are also crucial. BDG has a high moisture content, making it prone to spoilage and mold growth if not handled correctly. Poor storage can lead to contamination and nutritional loss, which is why drying it properly and keeping it in airtight conditions is essential for maintaining its quality (Jones and Roberts, 2019).

Finally, blending BDG with high-energy ingredients like maize or fat sources can help balance the feed's nutrient profile. Since BDG is relatively low in energy, combining it with other high-energy components can support better growth and productivity in livestock. This way, farmers can make the most out of BDG while ensuring animals receive enough energy for optimal performance (Moran, 2018).

By applying these strategies, BDG can become a more reliable and nutritious part of animal feed, helping farmers reduce costs without compromising on quality.

Nutritional composition of brewery waste

When selecting an unconventional feed ingredient, assessing its nutritional composition is crucial to determine its optimal replacement level without compromising animal performance. As shown in Table 1, the nutritional profile of brewery waste varies significantly due to differences in raw materials, fermentation processes, and drying methods, as illustrated in Table 2. Since BDG is low in energy, combining it with high-energy ingredients can enhance growth and productivity in livestock.

According to NRC (1994), BDG contains 25.3% crude protein (CP), 6.3% crude fat and around 2080 Kcal/Kg metabolizable energy and is also a good source of B vitamins. BDG can be a potential substitute for a part of maize and soya bean meal in chick's diet. BDG in broiler diet compared to ground corn caused an improvement in body weight gain and increased profit margin (Anyanwu *et al*., 2008).

Effect of brewery waste based ration on performance and feed utilization of broiler chicken

Brewery waste can be used instead of a part of the grain usually fed to poultry. Research studies (Table 3) pertaining to growth performance and feed utilization of broiler fed brewery waste tends to at least maintain, even if not, improve the performance of the birds. This has been attributed to the energy and protein content being like the maize grain.

Studies indicate that increasing BDG inclusion in broiler diets lowers dietary metabolizable energy without compensatory feed intake, leading to reduced body weight (Denstadli *et al*., 2010a; Kokol *et al*., 2012; Wondifraw and Tamir, 2014). The high-fiber content of BDG, rich in non-starch polysaccharides, may hinder nutrient digestion and absorption, reducing body weight gain (Alabi *et al*., 2014). Variations in BDG sources and experimental conditions likely contribute to conflicting findings.

FCR is generally not strongly affected by BDG inclusion (Ashour *et al*., 2019), though some studies report a decrease in FCR with higher BDG levels due to reduced body weight gain (Alabi *et al*., 2014). The presence of tannins and non-starch polysaccharides in BDG interferes with nutrient absorption and enzyme activity, lowering feed utilization efficiency (El-Hack *et al*., 2019).

Blood biochemical parameters of broiler chicken fed brewers' dried grains based ration

Brewery waste, free of major anti-nutritional factors, is a high-energy maize replacer (Olayemi *et al*., 2007). However, brewery waste may carry harmful microbes or chemicals, making blood biochemistry vital for assessing its effects on broilers. Very few studies have been conducted on the evaluation of blood biochemical parameters of broiler chicken fed brewery waste based ration (Table 4). In this paper, no effect on haematological profile has been found on broiler chickens when fed brewer based diet (Ashour *et al*., 2019; Parpinelli *et al*., 2020; Kokol *et al.*, 2012)

No substantial impact of BDG inclusion was detected by Ashour *et al.* (2019) on any of the serum biochemical constituents, except from globulin, A/G ratio and HDL-cholesterol. These results observed may be because of the existence of bioactive components in BDG. Decreasing the concentration of serum LDL might be because of minimizing microbial intracellular pH (Abdo and Zeinb, 2004). The inhibition of microbial enzymes forced the bacterial cell membrane to use energy to release acidic protons, which leads to a decline in intracellular pH (Aruna and Srilatha, 2012).

Effect of brewers' dried grains based ration on nutrient utilization in broiler chicken

Any change in the nutrient digestibility and nutrient utilization is indicative of the effects of the dietary interventions on the activity of digestive enzyme, intestinal integrity and ability of animal for voluntary dry matter intake. Research on BDG inclusion in broiler diets shows mixed effects on nutrient utilization. While some studies reported no negative impact on nutrient digestibility or dry matter intake (Swain *et al*., 2012; Esonu *et al*., 1999; Khalili *et al*., 2011; Wondifraw and Tamir, 2014; Diriba, 1991), others found significant differences. BDG levels ≥9% reduced OM, CP, EE, and NFE digestibility (Ashour *et al*., 2019), though CP digestibility peaked at 3–10% BDG (Aghabeigi *et al*., 2013). Higher BDG levels impaired protein digestibility (Denstadli *et al*., 2010b) and nutrient absorption due to fiber-mineral interactions, though effects remained minimal up to 20% inclusion (Adama *et al*., 2007).

Effect of brewers' dried grains based ration on carcass characteristics of broiler

Since broilers are raised for meat, assessing carcass characteristics is essential to evaluate the impact of brewery waste in their diet. As summarised in Table 5, several research studies indicate that BDG inclusion does not negatively affect major carcass traits (López and Carmona, 1981; Pires Filho *et al*., 2021; Chumpawadee *et al*., 2008; Józefiak *et al*., 2004). Most carcass parameters remain unchanged with BDG supplementation, except for gizzard percentages, which varied among groups (Kokol *et al*., 2012).

Some studies, however, report significant differences in dressing percentage and abdominal fat with increasing BDG levels (Ashour *et al*., 2019). Dressing and fat percentages decreased gradually from 6% to 12% BDG, likely due to lower body weight. Minor changes in dressing percentage were observed up to 20% BDG inclusion, but higher levels reduced abdominal fat and meat tissue without affecting bone tissue (López and Carmona, 1981). Overall, BDG can serve as a maize replacer while improving carcass quality.

Effect of brewery waste incorporation on economics of broiler chicken production

The major reason behind the search for non-conventional ingredients is the urgent need to cut down costs of production so as to enhance the economics returns. Hence, studies have been conducted to analyse the effect of brewery waste on economics of broiler ration (Table 6). Brewery waste, being a discard, is usually sold at lower prices compared to grain or sometimes even for free. This may help the poultry rearers to utilize the brewery waste as a replacer to costly energy rich ingredients. Moreover, feeding of brewery waste to broiler leads to reduced or no effect on feed intake and weight gain but lowered feed cost per kg weight gain (Ironkwe and Bamgbose, 2011). Contrarily, Adeniji and Adewole (2015) reported no significant differences in rearing cost, selling price, or feed cost per kg of diet when BDG was used.

Table 1: Challenges in Utilizing Brewery Waste as Feed in Broiler Diets

Category/Factors	Description	References
Nutritional Aspects		
Variability in nutrient composition	The nutrient profile of BDG depends on factors such as raw materials used in brewing, fermentation processes, and drying methods.	Ikram *et al*. (2017); Adeyemi and Olorunsanya, 2020
Presence of antinutritional factors	Tannins, polyphenols, or mycotoxins	Fărcas *et al*. (2014)
High Fiber Content	BDG is rich in fiber, which is not easily digestible by broilers	El-Hack *et al*. (2019)
Need for supplementation	BDG contains approximately 0.9% lysine and 0.4% methionine.	Lima *et al*. (2017)
Low Energy Content	BDG has lower metabolizable energy, affecting broiler growth performance.	Moran, 2018; Aghabeigi *et al*. (2013)
Technical Factors		
Bulkiness and High Moisture Content	Due to high moisture (~80%) content , making it bulky and difficult to transport and store. Even dried BDG may have storage issues due to hygroscopic properties.	Smith *et al*. (2021)
Processing Requirements	Drying BDG requires energy-intensive processes to reduce moisture and prevent spoilage	Lopez *et al*. (2012)
Poor Pelletability	BDG has a fine, powdery texture that affects pellet quality, making it difficult to incorporate into commercial broiler feed without binders.	Denstadli *et al*. (2010a)
Risk of Contamination	If not properly processed, BDG can harbor bacteria (Salmonella), fungi, or mycotoxins, posing a health risk to poultry.	Gonzalez Pereyra *et al*. (2011)
Economic and Logistical Factors		
Seasonal and Unreliable Availability	BDG supply depends on brewery production, which may vary based on market demands for beer.	Buss (2021)
High Transport and Storage Costs	Due to bulkiness and moisture content, transporting and storing BDG can be expensive	Smith *et al*. (2021); Mussatto *et al*. (2006)
Lack of Research and Standardization	There is limited research on optimizing BDG utilization in broiler diets, and nutrient composition varies widely between batches.	Parpinelli *et al*. (2020)

Table 2: Chemical/ Nutritional composition of brewery waste

Feedstuff	Location	DM	CP	CF	EE	Ash	ME	Reference
Brewer's dried grain	Ethiopia	91.01	22.58	23.43	3.06	4.74	8.14MJ/ kg DM	Wondifraw and Tamir (2014)
Brewer's dried yeast	Ethiopia	91.35	53.11	2.07	0.64	9.81	12.23MJ/ kg DM	
Brewer's dried grain	-	-	25	17.8	5.06	7.5	-	Swain *et al.* (2012)
Brewer's dried grain	Egypt	-	20.9	15.3	6.2	-	2840kcal/ kg	Ashour *et al.* (2019)
Brewer's dried grain	Norway	87.4	20.9	-	9.0	3.0	-	Denstadli *et al*. (2010b)
Sorghum Brewer's dried grain	Nigeria	93.50	31.60	7.80	13.73	16.00	3067kcal/ kg	Adama *et al*. (2007)

Table 3: Effect of brewers' dried grains based ration on performance and feed utilization of broiler chicken

Brewery waste	Bird and duration of feeding	Dietary treatments (% replacement of feed with brewery waste)	Effects			Reference
			Body weight gain	FCR	Feed consumption	
Brewer's dried grain yeast mixture [0% BDG and 20% brewer's dried yeast (BDY)]	324-day-old white leghorn chicks	0, 6%, 12%, 18%, 24%, 30%	Higher in the control diet (T1) than T5 and T6 (24%, 30%).	Lower for chicks fed T5 and T6 (24% and 30%)	-	Wondifraw and Tamir (2014)
BDG	96-3 week old Vanaraja chicks	0, 10 and 20%	Not affected	Higher for chicks fed at 20% level	Higher for chicks fed at 10 and 20% levels	Swain *et al.* (2012)
BDG	300 one-week old Hubbard chicks	0, 3, 6, 9 and 12 %	Higher in the control diet than groups with 6 and 12% inclusion	Not affected	Decreased with increasing dietary BDG	Ashour *et al*. (2019)

BDG	Day-old broiler chickens (Ross 308)	0, 10, 20, 30 and 40%	Lowest for groups with 40% inclusion	Higher for chicks fed at 30 and 40% level	No effect	Denstadli *et al*. (2010b)
BDG	714 one-day-old Cobb broiler chickens	0, 20, 40, 60, 80, and 100%	No effect	No effect	No effect	Parpinelli *et al*. (2020)
BDG	300 one-day old chicks 3 separate periods Period I: 0-4 weeks; Period II: 4-8 weeks; Period III: 8-12 weeks of age	0, 10, 20, 30 and 40%	Decrease during Periods I and II, when using 20% or more and Period III, when using 30% or more.	Decreased during Periods I and II, when using 20% or more, and Period III, when using 30% or more.	No effect	López and Carmona, (1981)
Sorghum brewer's dried grains (SDBG)		0, 10, 20, 30 and 40%	Higher in the control diet, 10% and 20% SDBG groups than with 30 and 40% SBDG inclusion	Higher for chicks fed at 30 and 40% level	Higher for chicks fed at 30 and 40% level (Total feed intake/ bird in gms)	Adama *et al*. (2007)
BDG	980 one-day-old male broiler chickens; up-to day 63 of age	0, 20, 40, 60, 80, 100, and 120 g BDG/ kg	Linear reduction in weight gain from d 0 to 21, 0 to 42, and 0 to 63, a	Linear increase as dietary BDG increased.	Feed intake of broiler chickens reduced from d 0 to 42 with increased BDG inclusion.	Pires Filho *et al*. (2021)

Table 4: Effect of brewers' dried grains based ration on blood biochemical parameters of broiler chicken

Brewery waste	Bird and duration of feeding	Dietary treatments (% replacement of feed with brewery waste)	Effects		Reference
			Haematological profile	Blood biochemical profile	
BDG	300 one-week old Hubbard chicks	0, 3, 6, 9 and 12 %	No effect	Highest globulin concentration value recorded for groups with 3% BDG. Best albumin/globulin ratio (A/G) recorded for groups with 9% BDG inclusion. Serum HDL concentration recorded the highest value for chicks fed 12% BDG.	Ashour *et al.* (2019)
BDG	714 one-day-old Cobb broiler chickens	0, 20, 40, 60, 80, and 100%	No effect	Highest values for AST and ALT recorded for groups with 60 and 80% inclusion.	Parpinelli *et al.* (2020)
BDG	980 one-day-old male broiler chickens	0, 20, 40, 60, 80, 100, and 120 g BDG/kg	-	A linear increase on serum glucose and total protein and a linear reduction in alanine amino transferase was seen as dietary BDG increase.	Pires Filho *et al*. (2021)

Table 5: Effect of brewers' dried grains based ration on carcass characteristics of broiler chicken

Brewery waste	Dietary treatments (% replacement of feed with brewery waste)	Effects on carcass characteristics		Reference
		Carcass traits	Organ traits	
BDG	0, 10 and 20%	Eviscerated yield percentage, wing and neck higher for 10-20% BDG diets; Relative weight of drumstick, abdominal fat and caeca lower for 10–20% BDG diets.	Relative weights of gizzard and thymus higher for 10–20% BDG diets.	Swain *et al*. (2012)

BDG	0, 3, 6, 9 and 12 %	No effect on carcass and giblet percentages. Dressing and abdominal fat percentages decreased with the increasing BDG level in the diets from 6% to 12%	No effect	Ashour *et al*. (2019)
BDG	0, 10, 20, 30 and 40 %	Relative caecal weight not affected by BDG inclusion.	Relative weights of gizzard higher for 40% BDG diets.	Denstadli *et al.* (2010b)
BDG	300 one-day old chicks 3 separate periods 0-4 weeks; 4-8 weeks; 8-12 weeks of age	No effect on dressing percentage in all periods.	Decrease in digestive tract weight and muscle (%) with increase in BDG inclusion levels in Period 1. Increase in bone (%) with increase in BDG inclusion levels in Period 1.	López and Carmona, (1981)
BDG	980 one-day-old male broiler chickens; 0, 20, 40, 60, 80, 100, and 120 g BDG/kg	No effect	Pectoralis minor yield and the relative weight of gizzard increased at d 21 and d 63 and pancreas increased at d 21 and d 63 with BDG inclusion rates.	Pires Filho *et al.* (2021)

Table 6: Effect of brewers' dried grains based ration on economic profile of broiler chicken

Brewery waste	**Effect on cost economics of poultry production**	**Reference**
Brewer's Dried Grain Yeast mixture	Treatment group with 30% inclusion showed lowest feed cost/kg live weight gain.	Wondifraw and Tamir (2014)
Brewer's dried grain	Treatment group with 20% inclusion revealed highest net profit.	Swain *et al*. (2012)
Maize/sorghum-based brewer's grains	Incorporation at 15-30% level in broiler diet showed decreased feed cost/kg weight gain	Esonu *et al*. (1999)
Brewer's dried grain	Incorporation at 9% BDG recorded the best economic efficiency value compared with the other treatments.	Ashour *et al.* (2019)
Sorghum Brewer's dried grain	No effect	Adama *et al*. (2007)

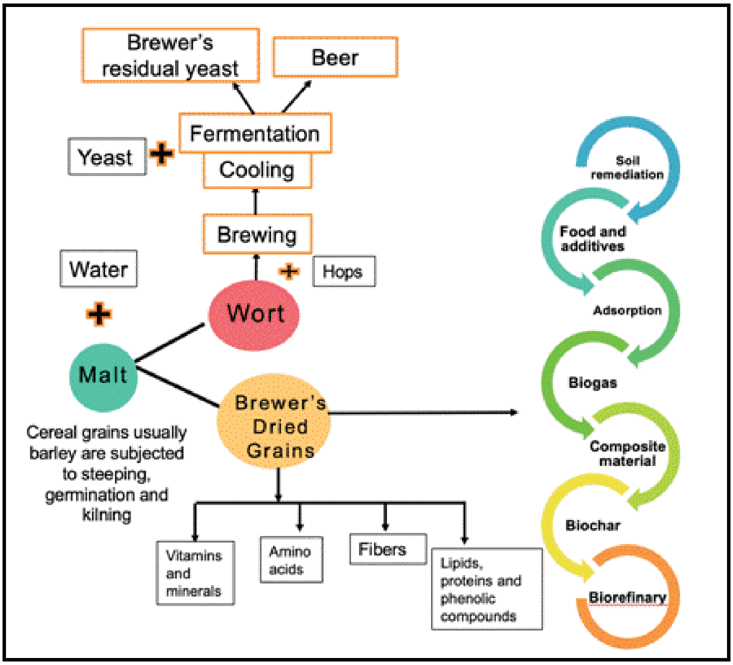

Fig.1. Schematic diagram depicting production process of Brewer's dried grains, their composition and applications (Generated using PowerPoint 2013)

CONCLUSION

Brewery waste mainly brewers' dried grains, which is one of the most wasted foods in most of the countries, could be used as an unconventional feed for the poultry and livestock with the help of modern brewery waste utilisation methods and technologies. Use of brewers' dried grains for broilers promises reduction of the feed cost, further enhancing economic returns. Several studies have indicated that the utilisation of brewery waste in the broiler diets does not produce any ill/adverse effects in the birds. However, results may vary due to difference in the nutrient composition of brewers' dried grains. This further demands the more detailed interrogation of use of brewers' dried grains for the poultry.

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