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# Glycerol – An alternate energy source for livestock feeding

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## ABSTRACT

***Glycerol, is being an attractive feed ingredient for cattle, is a by-product of a wide range of industrial applications. Glycerol has potential value in livestock feeding since it improves feed efficiency, metabolism, and can avoid ketosis. Research indicate that glycerol can be a suitable partial grain replacement in the diet of cows during the transition period and at early lactation. The impact on milk yield is not significant, but glycerol mostly decreases milk fat content. The inclusion of glycerol in the dairy ration has an effect on ruminal fermentation patterns. Glycerol is rapidly fermented in the rumen into propionate, and it is metabolized to glucose in the liver through the process of glycogenolysis, additionally, glycerol administration to ruminants can reduce greenhouse gas emissions. The purpose of this review is to highlight the potential benefits and drawbacks related to the use of glycerol in cattle. Glycerol, from biodiesel Industries, must be purified in order to make it useful product for livestock feeding. The use of glycerol in ruminant nutrition can be justified for several reasons: (i) as a source of energy, (ii) as glycogenic precursor, and (iii) it may have an effect on milk composition. The high energy value of glycerol provides the opportunity to use it as a partial substitute of grain in dairy rations. Supplementation of glycerol in dairy animals diet is associated with increased propionate, butyrate, valerate, and isovalerate concentrations in the rumen. Glycerol can be used as 10%–15% of the dietary dry matter (DM) and is well-established tool for treatment for ketosis in cows. Glycerol increases plasma glucose and may reduce non-esterified fatty acids and hydroxybutyrate levels. The dietary supplementation of glycerol does not have a direct effect on DM intake, milk yield, or milk composition. However, some researcher reported an increase in milk yield after glycerol supplementation associated with decreased milk fat concentration. It is also possible that the concentration in the milk of odd-chain fatty acids and cis-9, trans-11 conjugated linoleic acid may increase after glycerol application.***

***Keywords**: Dairy Cows, Glycerol, Metabolism, Ketosis, Rumen Microorganism*

## 1. INTRODUCTION

Increased concern on greenhouse gas emission, global warming and decreasing fuels have created the importance of an alternative source of energy for the transportation vehicles. Biofuel as an alternative fuel source, which releases less carbon dioxide, carbon monoxide, sulfur and nitrogen oxides upon combustion. These environmental friendly features of biodiesel make it a potential alternative to the conventional fuels. Biodiesel can be derived from the edible or non-edible source of triglycerides. During the biodiesel extraction process, crude glycerol (CG) is obtained at the rate of 10% as a byproduct of trans-esterification process. Crude Glycerol so obtained is chemically composed of catalysts, salts and fatty acids. Purification process of crude Glycerol >95% highly cost involving process (0.28 USD/L production) and time consuming too. Hence, economical management of CG is the need of time, one such alternative way is its utilization in animal food chain as an energy source. Glycerol is a glycogenic intermediate product of fat digestion converted to glucose by the action of key enzyme glycerol kinase. The CG undergo glycolysis and TCA cycle to liberate ATP. The digestible and metabolizable energy content of CG are comparable with the commonly used cereal grains in livestock feeding. So, CG can acts as a bridging gap between the biodiesel industry and livestock production, and can be used as an energy source as a partial replacement of grains in pig, poultry, goat, feedlot cattle and dairy cows. This review provides an overview of utilization of CG and its effect on production performance of different livestock species.

Glycerol obtained from biodiesel industry is called crude glycerol (CG) since it is mixed with the impurities like catalysts, salts and fatty acids. Use of vegetable oils as a source of triglycerides for biodiesel production competes with the human food chain. Keeping this in mind many research studies took place to use non-edible oilseeds, waste oils, byproducts of the slaughter house, algae etc., as an alternative source of triglycerides. Many changes and improvements have been adopted in the method of extraction process by using different types of catalysts, enzymes, alcohols, different temperature and pressure combination to decrease the cost involved and improving the efficiency of biodiesel extraction (Refaat, 2010). Currently, the biodiesel production in the world is around 29.7 billion liters which could create a huge amount of CG availability (REN21, 2015). Purified CG (>95%) are being used in the food, cosmetic and pharma industries. Purification of CG to 99% purity is a costlier affair, as it requires 0.28 US$/L of production. The presence of impurities in CG affects the operational cost of the industrial process and also not feasible under small or medium scale biodiesel plants (Posada et al 2012).

## 2. CHEMICAL COMPOSITION OF CRUDE GLYCEROL

After biodiesel extraction, Crude Glycerol consists of impurities like fatty acids, esters, methanol, soap, and catalysts. The color of Crude Glycerol depends on the source triglycerides used for biodiesel extraction and may varies from light brown to dark brown (Hansen *et al.*,2009). Crude Glycerol density ranged from 1.01 to 1.20 g/cm3 and pH ranges from 6.4 to 10 and that of pure glycerol is 1.31 g/cm3 and 6.4 respectively (Hu *et al.*,2012). Composition of crude glycerol depends on catalyst used in the production of biodiesel. (Yang *et al.*,2012). Crude Glycerol can obtained from six different sources of triglycerides (mustard, rapeseed, canola, crambe, soybean and waste cooking oil) contained 0.06 to 0.44%, 1 to 13% and 75 to 83% as protein, fat and carbohydrate, respectively. Almost 90% of ash in crude glycerol consists of sodium chloride derived from the catalyst used during extraction process (Orengo *et al.*,2014; Chanjula *et al.*,2016b). Crude glycerol contain other minerals such as Ca, P, K, Cu, Zn, Mg, and Mn which present in negligible amount, may impact little on feeding. (Jung & Batal, 2011; Shin *et al.*,2012). Among all constituents of the crude glycerol, methanol is more important because of its toxic effect on central nervous system. Methanol causes blindness by converting into toxic metabolites formaldehyde and formic acid (Dorman *et al.*,1993). However, till now no adverse effects had been reported in any species of animals fed crude glycerol.. The lower level of lipid to water partition coefficient of methanol shows that microorganisms having a better tolerance to methanol than the ethanol (Patterson & Ricke, 2015) Methanol concentration in crude glycerol depends on the production process and stock feeding. According to European Food Safety Authority (EFSA, 2010) limit of methanol in crude glycerol is 0.5% in the vegetable origin feedstock whereas, FDA (2010) allowed maximum up to 150 ppm of methanol in the final animal feed. However, Lage et al. (2014b) demonstrated no adverse effects even at 8.7% of methanol in feed lot goats. It has been seen that the residual methanol will evaporate during feed processing and storage due to its volatile nature. Silveira et al. (2015) in his pig experiment used crude glycerol derived from pork fat which was liquefied at 65.5°C found 0.0% of methanol indicating evaporation at that temperature.

## 3. CRUDE GLYCEROL IN ANIMAL FEEDING

At present, India has 20 large biodiesel plants producing around 135 million liters of biodiesel and 2,219 million liters of bioethanol per year (USDA, 2015).

National Biofuel Policy of India (2015) decided to blend 20% of bio ethanol and biodiesel with petrol and diesel respectively by the end of 12thfive year plan, to decrease green house emission, climate change mitigation for environmentally sustainable development, apart from other advantages like creating new employment opportunities. In order to achieve the target of 20% blending national biofuel policy set a target of dedicating 11.2 to 13.4 million hectares (Mha) of land to Jatropha cultivation by the end of its 11thFive-Year Plan. However, it was a failure due to unawareness of farmers regarding agronomic practices of Jatropha cultivation, lack of field validation and standardization of oil yield and many other reasons which is behind the scope of this review (Singh *et al.*,2013; Edrisi *et al.*,2015). Several state governments along with the central government are providing incentives to farmers for planting Jatropha and other non-edible oilseeds. The expected increase in biodiesel production creates the excess availability of CG as a byproduct which can be utilized as an energy source for the livestock's which in turn reduces the dependence on the cereals and cereal by-products.

## 4. NUTRITIVE VALUE OF CG

Chemically, glycerol is a sugar alcohol and highly soluble in water. Sweetish taste increases its palatability (Groesbeck *et al.*,2008). A peptide hormone (Ghrelin) secreted from the stomach mucosa is considered as hunger hormone, increase in acyl ghrelin in pigs fed with Crude Glycerol in their diet, shows the tendency of appetite increse (Orengo *et al.*,2014). Ingested crude glycerol absorbed by passive diffusion and acts as a readily available source of energy. For initiation of glycerol utilization Glycerol kinase is a key enzyme in the liver. this converts glycerol to glycerol 3-phosphate, which in turn get converted to glucose by gluconeogenesis or oxidized to give energy by glycolysis or TCA Cycle. Due to viscous nature it reduces the dustiness of feed in mash type of feed, but increasing it more than 8% of the diet in pig resulted in feeding difficulty due to the formation of an aggregate of feed to firm mass (Hansen *et al.*,2009). A similar finding was reported by Cerrate et al. (2006) in poultry birds increasing CG up to 10% affected the flow rate of feed in tube feeder and pellet quality. Whereas, the addition of CG prior to pelleting increased the pellet durability and feed mill production efficiency at 9% level in piglet diet preparation (Groesbeck *et al.*,2008).

## 5. EFFECT OF GLYCEROL ON RUMEN PROCESSES AND METABOLISM

Glycerol is completely fermented in the rumen to volatile fatty acids (VFA), especially propionate and butyrate (R_emond *et al.*,1993; Silva *et al.*,2014), which decrease ruminal pH and cause negative effects on microbial protein synthesis, low cellulolytic activity of *Ruminococcus flavefaciens* and *Fibrobacter succinogenes*, (Roger *et al.*,1992; Kijora *et al.*,1998). Kijora et al. (1998) decreased ruminal pH and acetate to propionate ratio in experimental intra ruminal administration. The decreased acetate to propionate ratio is beneficial, to increases milk production and depress milk fat synthesis. Linke et al.(2004) reported that glycerol administration at 1 kg/d decreased acetate and increased propionate and butyrate after four hours of feeding. Kristensen and Raun (2007) observed, decreased acetate and increased butyrate, without affecting propionate by glycerol infusion into the rumen. In other experiment, Trabue et al. (2007) reported that glycerol increased concentrations of butyrate, valerate, and caproate in vitro. DeFrain et al. (2004) observed increased proportion and butyrate by drenching cows with glycerol. The varying effect of glycerol administration on ruminal VFA may be due to purity of the glycerol, different doses, and the nature of the diets. The effect of glycerol on ruminal fermentation depends mainly on rate of glycerol disappearance in the rumen. The rate of glycerol disappearance in the rumen is very fast due to the fast adaptation of ruminal microbes to it. (Kijora et al.,1998; Porcu *et al.*,2018). Kijora et al. (1998) reported that 85% of the twice-daily infusion of 200 g glycerol disappeared in the rumen after 2 h of feeding and increased plasma glycerol in cow fed with crude glycerol. R_emond et al. (1993) reported that most of the glycerol is absorbed directly in the rumen; however, it is difficult to determine the relative amount of absorption as glycerol vs. fermentation. The rates of glycerol disappearance range from 1.2 to 2.4 g/h in the rumen. (R_emond *et al.*,1993), Kristensen and Raun (2007) suggested net absorption of glycerol in the rumen is limited even with the administration of large doses. They reported only about 10% recovery in porthel vein of administered glycerol (925 g/d per cow), and taken up by the liver for the synthesis of glucose.

## 6. EVALUATION OF GLYCEROL ADMINISTRATION IN DIETS OF LACTATING ANIMALS

In vitro technique evaluates of crude glycerol before feeding it to animals. However, the doses of glycerol used in in vitro experiments differ from those used in the live animals. Avila et al. (2011) reported that barley grain replacement with increasing proportion of glycerol linearly increased in vitro propionate and reduced acetate concentrations, while Abo El-Nor et al. (2010) reported no change in in vitro experiment of DM degradability with glycerol administration at two different doses. However, Van Cleef et al.(2018) observed linear increases in vitro Dry matter digestibility and a decreased in vitro NDF degradability with glycerol supplementation. Similar findings were reported by Abu Ghazaleh et al. (2011) who reported improved DM digestibility and depressed in vitro NDF degradability to the reduction in the numbers of microorganisms involved in fiber digestion. Increased dietary glycerol concentration decreased total gas and carbon dioxide production due to lowered ruminal fermentation and VFA production (Lee *et al.*,2011; van Cleef *et al.*,2018). Ferraro et al. (2016) evaluated the effect of glycerol combined with corn silage or alfalfa on in vitro ruminal fermentation and observed a lowered gas production. Van Cleef et al. (2018) noted a tendency for a linear reduction of methane production with glycerol administration due to the negative effects of glycerol on the growth and activity of fiber-fermenting bacteria (Abu Ghazaleh *et al.*,2011). Lee et al. (2011) also reported that glycerol has the ability to reduce in vitro methane production, reported a positive effect of glycerol on dietary energy utilization efficiency. In contrary, Avilaet al. (2011) did not find any reduction in methane production when glycerol was administered after 48 h incubation. As previously noted, the dose, the purity and application method of glycerol and nature of incubated substrates among other factors are responsible for the inconsistency of results of experiments on in vitro methane production.

## 7. EFFECT OF GLYCEROL FEEDING IN NEWBORN ANIMALS AND TRANSITION COWS

There are 3 lactation phase in the life of dairy animals: growth, dry or non-lactating, and lactation Phase. Therefore, the effect of glycerol feeding to dairy animals will depend on the lactation phase. During the early phase of growers, dehydration and energy deficiency, as a result of diarrhea, are important causes of mortality (Barrington *et al.*,2002). Oral rehydration solutions maintain the fluid and electrolyte balance. Information available in the literature on the effect of feeding glycerol to new-borns is very less. Oral feeding of glycerol with oral rehydration solutions can play an important role in treating new borns suffering from metabolic disorders through affecting blood glucose. Omazic et al.(2013) compared oral rehydration solution containing Glucose with oral rehydration solution containing glycerol and observed that calves given glycerol oral rehydration solution had better plasma glucose levels while calves given oral rehydration solution containing glucose have lower plasma glucose level. Though plasma glucose level is a good indicator of energy status of an animal, the result suggested that glycerol enhances energy supply in oral rehydration solution compare to glucose. Additionally, the numbers of enterobacteria and lactobacilli have no effect on glycerol inclusion in the oral rehydration solution; However, the glycerol-utilizing Lactobacillus reuteri was detected in calf faeces. During transition period, there is an increase in energy demand by the mammary tissue for lacto genesis, resulting in cows suffering from low and high levels of blood glucose and insulin and blood non-esterified fatty acids (NEFA) and beta-hydroxybutyric acid (BHBA), respectively (Ingvartsen and Andersen, 2000). Glycerol, as a prophylaxis for ketosis in transition cows, was evaluated in many research (Goff and Horst, 2001; DeFrain *et al.*,2004). Glycerol administration in fresh animals improves blood glucose and lowers NEFA and BHBA concentrations, Many years back, Johnson (1954) reported the use of glycerol to prevent ketosis. To evaluate the value of glycerol in treating ketosis, Donkin (2008) recommended glycerol can be fed from 5% to 8% of the dietery DM for transition cows, but Schr€oder and Südekum (1999) observed no negative effect on DMI at 50% of the starch replacement by 10% glycerol in the dairy cattle diet.

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