Poultry industry is playing the biggest role in the industries of the developing countries with respect to the capital generated by this industry as well as the fulfillment of the nutritional requirements. The improvement in the production potential of the existing layer population is more imperative as compared to the size of the flock. In this aspect induced moulting is a valuable as well as economical practice especially for the developing countries. There are many methods to induce the moulting which are under investigation to prove the competency over the other. So, there was a need to compile these extensive studies regarding the induced moulting with relation to different aspects. The review of the literature is always the basic necessity to make further hypothesis. In addition to the different moulting programmes the supplementation of the molted birds with protein and probiotics will also be a provoking idea in order to improve the production potential of the molted layers.

**Key words:** Induced moulting; Layers; Protein; Probiotic.

Poultry eggs are the most economical nutritional source for an economically underdeveloped country and poultry meat is the preferred meat that makes the attention over this sector. Poultry sector is one of the largest and still growing industry of India. It shows that yet the maximum production potential of commercial layer in the developing country could be further explored and in this regard technical know how and skills should be summarized to make more comprehensive future recommendations.

In the procession of production cycle as the layers get older, their egg production and egg external quality decrease (Hurwitz et al., 1998). Forced moulting can restore their reproductive system capacity, and promote a new laying cycle (Colvara et al., 2002). Different methods have been used to initiate moulting include feed and water withdrawal, feeding high dietary zinc, photo period reduction (Sandhu et al., 2006), feeding low calcium diet (Breeding et al., 1992) etc. The induced moulting is an economical practice to explore or enhance the production potential of the spent layers. To get the early recovery from the moulting stress and to achieve the better production the supplementation with the extra protein and probiotics to the molted birds will be fruitful thought for future experimentation as well as practical implication. However, the effect of experimental protein deficiency on poultry is fairly well documented (Scott et al., 1978). These include reduced growth, reduced feed consumption, decreased egg production and egg size, and loss of body weight in adults. In a field occurrence, when the feed (CP 12.8%) was replaced by the protein sufficient feed (CP 17.8%) the disease (protein-deficiency) was cured in turkeys and chickens (Ekperigin et al., 1983).

Commonly Lactobacillus is used by different researchers in their study as probiotic. Nahashon et al. (1996) has documented that feeding Lactobacillus increased daily feed intake as well as consumption, egg size and decreased intestinal length. So, after birds have molted the supplementation of the diet with additional protein and probiotics might have the effect to get the early recovery from stressful condition as well as better production performance.

Moulting program in poultry is based on the natural moulting process as the wild birds undergo annually. Induced moulting is used in the poultry industry to increase the reproductive lifespan of
layers leading to new laying cycles (Laurentiz et al., 2005).

**Efficacy of Moult:** The moulting efficacy is mainly depending upon the body weight loss and feather replacement. According to Baker et al. (1983) body weight losses levels between 25 and 30% promote better post-moulting production in a second laying cycle. Photoperiod reduction occupies a discrete and important role in induced moulting as by the interruption of the follicular hierarchy (Brake and Thaxton, 1979). Induced moulting with total light restriction requires 8 days to cease production while, hens forced molted by conventional method cease production in 5 days (Hembree et al., 1980). However, according to Brake and Thaxton (1979), post-moulting productive improvement is related to the regression. Therefore, post-moulting results are associated with organ regression levels obtained during the moulting process (Ruszler, 1998). Anish et al. (2008) found that pattern of reproductive regression during moulting by feed withdrawal and high dietary Zn diet is different from each other. Sundaresan et al. (2007b) concluded that cytokines play a major role in regression of the ovary and oviduct during induced moulting in chickens. Also, the reduction in the ovary weight depends on the duration of fasting or the level of body weight loss (Berry, 2003). In contrast to this fifteen per cent body weight loss results in heavier eggs as compared to 20-25% loss (Hembree et al., 1980; Buhr and Cunningham, 1994). Forced moulting and daily egg production are positively and significantly correlated with each other as production of eggs reduces to 70.3% - 82.3% after induced moulting when compared to the peak production in the 1st production cycle that is before moulting (Cheshmedzhieva and Dimov, 1989). Improvement in production rate is observed by increase in the length of rest period from 14 to 21 days. Sundaresan et al. (2007a) concluded that lipopolysaccharide-induced TNF-α factor (LITAF) might be one of the major transcription factors controlling reproductive regression in chickens, as the expression levels were associated with the regression pattern.

**Methods of Moult:**

- **Fast induced moulting:** Fast induced moulting programme, widely practiced on egg production facilities throughout India, deprives egg laying hens of food in order to rejuvenate their reproductive tracts and stimulate additional cycles of egg production. “ANIMAL WELFARE BOARD OF INDIA” ordered on 9th March 2011, all poultry farmers in India to immediately discontinue starvation force moulting regime, stating that the practice is in violation of India’s Prevention of Cruelty to Animals Act, and a punishable offence. This fast induced moulting programme has already been prohibited in Australia and European Union, and prohibited in the US by the egg industry’s animal husbandry programme.

- **Fasting of hens for a particular length of time, or to a targeted body weight is used as conventional induced moulting strategies.** Regarding the length of moulting, it could be defined as the time taken from the initiation of fasting till the birds reaches up to 50% egg production, which may varies with the particular moulting technique and conditions (Khoshoei and Khajali, 2006). The short fasting for 4 – 6 days, medium fasting (10 days) and long fasting (12 – 16 days) are the most commonly used fasting programmes by the commercial farmers (Ruszler, 1998). According to Ricke (2003) the fasting has negative impact on the welfare of hens as it makes the molted hens more susceptible to Salmonella enteritidis that increases the concerns about the welfare of hens, hence evoked the issue about the obliteration of induced moulting. However, keeping in view the economic benefits of induced moulting alternative techniques are being under investigation. The results of Khoshoei and Khajali (2006) supports that the non feed removal methods are reasonable in a comparison to the conventional feed removal methods.

- **Hormonal therapy to induce molt:** Molt induction in layers without loss of body weight is possible with the hormonal therapy (Tilbrook et al., 1992). Moult in laying hens can be induced with the use of iodothyronines. A lower (0.2mg/bird) or a higher (0.4mg/bird) dose of thyroxin for 21 consecutive days has been used to induce molt (Szelenyi et al., 1988). Injection of 0.7mg thyroxine or triiodothyronine for three consecutive days is also used (Verheyen and Decuypere, 1983). One of the methods of induced
molt in domestic hens is by progesterone administration at a dose rate of 50mg/kg b.w. (Szelenyi et al., 1988) without dark period. Agarwal et al. (2012) indicated that Luteinizing Hormone Receptor may have an important role in reproductive tissue regression during molting.

**Mineral induced molting procedures:** The use of high levels of dietary Zn, Cu or Al in the form of a soluble salt has also been used successfully. High level of dietary Zn reduces feed intake and consequently results in cessation of egg production (Breeding et al., 1992; Sandhu et al., 2007 and Sundaresan et al., 2008). Supplementation of 1% ZnO for 14 days resulted in rapid decline of feed intake (Shippee et al., 1979). Dietary Zn has specific effect which is independent of anorexia (Breeding et al., 1992). Dietary zinc induced molting was proved to be better in improving the immune status (Sandhu et al., 2007) as well as the production performance (Sandhu et al., 2006) and now becoming the favorable alternate to the conventional fast molting procedures (Koch et al., 2007; Koelkebeck and Anderson, 2007). The better response of pituitary hormone secreting cells was also seen in the dietary zinc induced molting when compared to fast induced molting (Sandhu et al., 2008) The moderate levels of Zn (ZnSO₄, 2800ppm) and Ca (400ppm) in molt diet effect reproduction, which is independent of anorexia. Subsequent studies characterize the site of action of Zn at the ovary (Johnson and Brake, 1992). Supplementing Zn in Ca deficient diet is practically beneficial because it inhibits ovarian function without causing undue stress related to the condition of anorexia (Brake, 1993).

**Food waste material as inducer of molt:** The use of molt induction diets made by the addition of grape pomace, wheat middlings, cottonseed meals and jojoba meal were experimented and proved to be successful alternate molt induction diets (Seo et al., 2001; Keshavarz and Quimby, 2002). But according to Landers et al. (2005) all these ingredients are essential waste of food processing and not a common food additive so their availability is scarce. He successfully used alfa alfa which is commercially and easily available as another alternate feed additive in the molt induction. McReynolds et al. (2006) and Dunkley et al. (2007) has also used alfa alfa in the diet of the layers and declared it as better alternate to induce molt.

**The impact of age on molting in layers:** Age of hens also accounts for the process of molting and egg production. Hens molted at 77 weeks of age produce less eggs but when molted at 66-71 weeks show best results with 35 percent body weight loss (Rolon et al., 1993; Sandhu et al., 2007). When birds are molted between 54-62 weeks of their age, egg production and egg shell quality increases. Mortality percentage is significantly correlated with molting age (Hazan and Yalcin, 1992). Natural molt occurs with advancement in the age and length of intensive production of a laying flock. The effects of age on plasma concentration of progesterone were studied by Joyner et al. (1987) who recorded progesterone levels of 4.29, 3.80 and 1.64 ng/ml for pullets, old layers and old non-laying hens, respectively. However, Etches (1996) indicated that molting occurs when plasma concentrations of steroids and gonadotropins are low. This is in agreement with the findings of Decuypere and Verheyen (1986) and Jacquet et al. (1993) who reported that changes in the reproductive functions during forced-molting were associated with reduced levels of luteinizing hormone and sex steroids. The major changes caused by molting within the hypothalamo-hypophyseal-gonadal axes result in temporary cessation of lay. So, with the increase in the age and with the passage of production cycle the fluctuation in the pituitary hormones are responsible for the natural molt.

**Moulting with relation to the strain of layer:** Single Comb White Leghorn Layers have greater ability to withstand stressful conditions resulting in less mortality as compared to other strains of layers. Less than 2% mortality occurs during the whole fast induced molting phase (McCormick and Cunningham, 1984) and 10 days of fasting results in 1% mortality (Severin, 1983; McCormick and Cunningham, 1987) in white leg horns.

**The impact of molting on the immune system:** The molting is a kind of stress and it is concluded that induced molting probably has a negative effect on the cellular component of the immune system of the molted birds (Holt and Porter, 1992). The process of molting has been shown to stress the immune function, promote systemic disease conditions and
impair the bird’s cellular immune system (Alodan and Mashaly, 1999). The heterophil to lymphocyte ratio is important, in heterophilia the heterophil to lymphocyte ratio increases which is an indicator of stress (Maxwell, 1993; Siegel, 1995), like moulting. The method of moulting is of prime importance regarding the impact of moulting on the immune status of the body. There was a significant increase in antibody production in zinc induced molted birds when compared to fast-induced molted birds, means it has positive effect on the parts of the immune system. The inclusion of Zn (30 ppm) in the diet of the turkeys improves the invitro phagocytic activity of the abdominal exudates cells (Kidd et al., 1994). Zinc is an important mineral regarding its role in the potentiation of the immune system (Bartlett and Smith, 2003). Even the deficiency of this mineral leads to the immune compromised situation and make the animal more prone to different infectious agents (Singh et al., 1992). The poor immune response in the fast induced moulting methods is may be due to the fasting stress which leads to elevated levels of circulatory adrenal corticoids (2002; Latshaw, 1991) which may also be the cause of impaired immune response and results in decrease number of circulatory leucocytes and decrease in the population of spleenic leukocytes (Holt and Porter, 1992). Thus zinc induced moulting could be preferred over the fast induced moulting, as this zinc has the effect in the potentiation of functions of many key tissues, cells and effectors of immunity, function of macrophages and T-lymphocytes (Singh et al., 1992).

The role of proteins in the production potential of the birds: The impacts of experimental protein deficiency including reduced growth, reduced feed consumption, decreased egg production and egg size, and loss of body weight were extensively studied by different researchers in human adults (Scott et al., 1978). Ekperigin et al. (1983) reported about the consequences after field occurrences of protein-deficiency in turkeys and chickens. The disease caused unthriftness, poor growth, and a sharp drop (18%) in egg production in a flock of 60-week-old white leghorn layers. The feed which was given already contained crude protein content of 12.8%. In each case, the disease was cured by replacing the protein-deficient diet with a protein-sufficient one (17.8%). The exhibition of pica was virtually eliminated, and a marked improvement in appearance and performance of the birds was noticed within a week. Togun et al. (2004) studied the effects of varying levels of crude protein and follicle stimulation on the recovery and performance of one hundred post molted, aged, Nera Black Hens. Follicle stimulation enhanced post-molt production performance especially the hen-day performance in birds on 16% CP diet. Johnson and Lohman (2003) suggests that as a result of breeding specialized hens which lay more frequently, the protein requirements of laying hens has increased. Traditional diets are no longer good enough on their own. So, the Supplementation of the diets with additional protein will give better results regarding production which will be of utmost importance in the molted layers. According to Al-saffar and Rose (2002) egg laying economics are directly related to the balanced diets fulfilling the amino acids requirement of the laying birds. Among the different amino acids methionine is most important and generally limiting amino acid of the layer diet. Even the diets with low CP but supplemented with amino acid especially methionine are feasible to alleviate the problems of protein insufficiency (Bunchasak and Silapasorn, 2005). Wu et al. (2005) reported the significant increase in the egg weight of the molted hens by increasing the dietary protein, fat, linoleic acid, lysine and methionine. Gunawardana et al. (2008) mentioned that increasing the dietary protein from 2-3 % could result in an increase of 6% in the feed intake of molted birds resulting in improved egg quality and production. Here is another matter of concern is the cost of the feed as with the supplementation the aim was to get the improved production at the less expense. So, the major problem regarding the poultry production is high cost of the feeds. This high cost is the main encumbrance in the expansion of the poultry population. This problem can be tackle by the use of cheaper and locally available sources of protein like groundnut cake, soybean etc. (Onwudike, 1981). The use of full fat soybeans is another remarkable substitute to other protein sources in the layer diet with a least effect on the cost of the feed Swick (1996) and without any negative impact on the performance of laying birds (Senkoylu et al., 2005). The essentials of egg production like riboflavin, thiamine, niacin, folic acid, choline and pantothenic acid could also be
furnished about 30 - 50 % from lecithin of whole soybean (Ruiz et al., 2004).

**The probiotics as production promoter in layers:**
Probiotics (meaning “‘for life’”) are defined as microbial cell preparations that have a beneficial effect on the health and wellbeing of the host (Fuller, 1989). Direct fed microbials benefit the host animal by stimulating appetite (Nahashon et al., 1993), synthesize vitamins, stimulate the immune system (Toms and Powrie, 2001), improve intestinal microbial balance (Fuller, 1989), produce the digestive enzyme (Saarela et al., 2000), utilize undigestible carbohydrate (Prins, 1977), stimulate lactic acid and volatile fatty acids production (Bailey, 1987). Regarding the variable results about using biological additives, the strain, concentration and form of them (viability, dryness or their products) should be considered. Feeding Lactobacillus increased daily feed consumption, egg size, nitrogen and calcium retentions and decreased intestinal length from 7 to 59 weeksof age (Nahashon et al., 1996). Tortuero and Fernandez (1995) have also seen some similar effects in hens performance. The probiotic reduced the plasma cholesterol and triglyceride, significant effect on egg yolk cholesterol but no significant decrease in feed consumption, egg production and egg weight (Mahdevi et al., 2005). Tortuero and Fernandez, (1995) showed that using vital biomass of probiotic supplements affects the egg weight significantly (P > 0.05). Complementary reports by the Nahashon et al. (1996) suggested that addition of biological additives did not influence the egg weight significantly. These controversial results might be related to the dosages of probiotic and concentration of bacteria used in the diet. Tortuero and Fernandez (1995) used diets containing increased number of bacteria per gram of feed comparing with Nahashon et al. (1996). Thus, increase of egg weight might be related to the vital form with higher doses up to 109 cfu gr-1 feed of probiotic. Mohan et al. (1995) reported that there is improvement in the physiological properties of the egg, but there are also some reports which have different opinions (Tortuero and Fernandez, 1995), that might be related to the strain of bacteria, concentration and the form of bacteria used (viability, dryness or their products). Another reason to variable effect of biological additives may be confounded by variations in gut flora and environmental conditions. Similarly probiotics studies in laying hens under different climatic and geographical locations has also shown the results like this (Miles et al., 1981).

The main action of probiotics can be summarized as a reinforcement of the intestinal mucosal barrier against deleterious agents. The characteristics and beneficial aspects of the probiotics could be summarized as in the tables below.

**Characteristics of an ideal Probiotic:** Be of host originNon-pathogenicWithstand processing and storageResist gastric acid and bileAdhere to epithelium or mucusPersist in the intestinal tractProduce inhibitory compoundsModulate immune responseAlter microbial activities Simmering and Blaut, (2001)

**Beneficial effects of Probiotic and Prebiotics:** Modify intestinal microbiota Increase production of VFASimulate immune system Reduce inflammatory reactions Increase B vitamin synthesisPrevent pathogen colonization Improve mineral absorption Enhance animal performance Decrease carcass contamination Lower serum cholesterol Decrease ammonia and urea excretion Adapted from Patterson and Burkholder (2003).

**CONCLUSION**

The review of the literature reveals that the use of the induced moulting is a useful tool to improve the production potential of the laying hens especially the economical aspect. However, there are different induced moulting programmes which vary in their spectrum of efficacy in addition to the production potential regarding different health parameters like immunity, immunocytochemistry, serum biochemicals etc. Some methods has advantage over the other based on these parameters like dietary zinc induced moulting shows better results regarding the immune status of the birds when compared to the fast induced moulting.

The compilation of all these studies will be a supportive report as to plan the further experiments to explore the dynamics of induced moulting. In addition to the different induced moulting programmes the supplementation, more specifically the protein through a plant source and probiotic addition in the feed/water will be a productive study. As the moulting is a stress full procedure and stress
has a negative effect on the gut micro flora. So, after moulting the supplementation with probiotic as well as with extra protein will be a supportive treatment, which may help birds to come out of that stress period earlier and give better production performance, but needs further investigations regarding the molted birds.

REFERENCES


