



Application of plastics in livestock production: An overview

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ABSTRACT

Plasticulture refers to use of plastics in agriculture in a scientific manner which not only improves the productivity but also optimizes the input resources. The plastic use in livestock farms is also becoming important, particularly for livestock products, for improving its keeping quality; livestock farm operations like storage of feed, feeding and watering devices; animal identification; milking machines and its tubings; milk cans; semen straws and AI sheaths, etc. Recently, the research work has been initiated for the usefulness of plastics in livestock shelter components like floor, wall partitions, protection panels, etc. under AICRP on PET project with ICAR-CIRG, Makhdoom and ICAR-NRCY, Dirang, Arunachal Pradesh for goats and Yaks, respectively as its animal science components. The main plastic products that are utilized on livestock farms are low density polyethylene (LDPE) and polypropylene (PP). This review paper discusses in brief about the plastic use in various stages of livestock production to marketing of its products.

Keywords: Goats, Livestock Production, Plastics, Shelter

The term ‘plastics’ is commonly used to describe a wide range of synthetic or semi-synthetic materials that are used in a huge and growing range of applications. They are organic materials similar to paper, wood or wool and are produced by using naturally available raw materials like cellulose, coal, natural gas, salt and crude oil. Plastics have become choice of the modern material due to its ability to make it possible to balance today’s needs with environmental concerns. There are different types of plastics, and they can be grouped into two main polymer families such as *Thermoplastics* - Plastics which soften on heating and then harden again on cooling and *Thermosets* - Plastics which never soften once they have been moulded. The All India Coordinated Research Project on Plasticulture Engineering and Technologies (PET) become operational in 1988 during VII Plan period (known as AICRP on Application of Plastic in Agriculture) to undertake research and extension activity in agriculture field. This project is operational at 14 centres located in different agro-ecological regions of India with its coordinating unit located at ICAR-CIPHET, Ludhiana. The mandate of the project is to develop strategies for use of plastics in agriculture with major emphasis on-surface covered cultivation, lining of ponds for rainwater harvesting, storage of water, micro-irrigation systems and mist formation; packaging, storage, transportation of agricultural produce and products;

aquaculture, and livestock management.

Plasticulture, i.e. application of plastics in Agriculture is fast becoming the most sought out technique to augment farm yields and consequent farm income, off-season cultivation of crops. Plasticulture refers to use of plastics in agriculture in a scientific manner which not only improves the productivity but also optimizes the input resources. According to research experts from Watershed Organisation Trust (WOTR) Pune and Hyderabad, in India (Arjuna Srinidhi and Divya Nazareth), plasticulture can help to realise the overall aim to double farmer’s income domestically by 2022, which is even more significant due to direct/indirect dependency of 50% of the population on agriculture for livelihood providing 14% contribution of agriculture to the national GDP.

The use of plastics revolutionised the performance of agriculture throughout the world in the era of climate change witnessing increasing temperature, decreasing and unpredicted rainfall, natural disaster due to imbalance, etc. This change is expected to increase infinitely and create havoc in the availability and utilisation of natural resources like water. Water is going to be the single most critical input that may create greater competition for its utilisation. Further, the erratic nature of rainfall during the key monsoon season also exposes national income to risk.

India supports 18% of the global population with 2.4% of land area and 4% of water resources thereby making the necessity of judicious use of water even more important. The conventional method of agriculture with liberal use of water happens to be the next to impossible event for realising profit in days to come. At this juncture, plastics

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play a significant role in conserving water for efficient utilisation for domestic use as well as for agriculture.

Therefore, the use of plastics in agriculture is becoming inevitable day by day, (i) for efficient and strategic use of resources like water, fertiliser, pesticides, (ii) for minimising the pre- and post-harvest losses of agricultural produce for maximising the productivity thereby achieving the cost effectiveness of the agricultural activities as an Agri-business sustainably. Similarly, the plastics use in livestock farms also becoming important particularly for livestock products for improving its keeping quality like milk, meat, egg etc. In addition, the use of plastics in livestock farm operations like storage of feed (plastic silage bags/films for covering silo pits), feeding and watering devices, animal identification (plastic ear tags), milking machines and its tubings, milk cans of different capacities and colour, semen straws and AI sheaths etc are being practiced. Recently, the research work has been initiated for the usefulness of plastics in livestock shelter components like floor, wall partitions, protection panels, etc. under AICRP on PET project with ICAR-CIRG, Makhdoom and ICAR-NRCY, Dirang, Arunachal Pradesh for goats and Yaks, respectively as its animal science components.

The main plastic products that are utilized on livestock farms are low density polyethylene (LDPE) and polypropylene (PP) [Borreani and Tabacco 2017]. LDPE is utilized to produce almost 70–85% of agricultural plastic products, while PP is also utilized for some other applications, such as for strings and nets to tie round bales. Most of the plastics consumed on livestock farms is utilized as LDPE films for animal feed conservation purposes/silos, feed and vitamin supplement packaging, grain storage bags, seed packaging, etc. The high density polyethylene (HDPE) is used in the form of bottle for manufacturing veterinary medicines, liquid fertilizers and agrochemical containers, in net form to tie bales. PP is also used to prepare seed packaging materials, solid fertilizer containers, strings and ropes, net to tie bales etc. Then these used plastics need to be disposed outside the farms when it is no longer usable, thus representing a cost for the farm.

Plastics in forage conservation

Generally, surplus green fodders and monsoon herbages are being conserved in the form of hay, haylage, silage, or straw bales in livestock farms especially in dairy farms. The introduction of plastic films revolutionised the forage conservation in the form of silage in wide variety of silo types: horizontal silos with bunkers and trenches or without walls (piles and clamps), wrapped or bagged bales (round and square bales; wrapped individually or inline), and pressed bags. It has been observed that the silage bags, bale wraps, plastic bunker silo covers and the net that is used to tie bales are the main plastic film products used on dairy farms that are made of LDPE/ LDPE coextruded with polyamides (PAs)/ ethylene vinyl alcohol copolymer (EVOH) (Borreani *et al.* 2007b, Borreani and Tabacco 2014). Borreani and Tabacco (2017) reviewed the amount

of plastics used for silage making in Italy and Ireland dairy farms and reported that the plastic films that are utilized to cover bunker silages represent 33–45% of the entire amount of plastics purchased by dairy farmers for feed conservation, depending on herd size. Bale wrapping is adopted widely on dairy and beef farms because of its greater flexibility, and the plastic consumption of stretch film represents about one-third of the plastic consumption of these dairy farms. The films utilized for silage conservation in dairy, beef and pig farms represented 80, 93 and 37% of the plastic purchased yearly. Mostly corn silage (mean DM range: 30–38%) was stored in horizontal silos covered with LDPE (100–250 μm thickness). It has been estimated that 0.17 kg plastic film is required to cover 1 ton of silage (0.53 kg/t DM). Hay bales are wrapped with four to six layers of 25 μm LDPE stretch film with the mean film consumption ranged from 0.7–2.1 kg/bale having 1.2–1.8 m diameter (Borreani and Tabacco 2017).

For better quality of silage materials, an ideal plastic film should have high mechanical properties (puncture resistance, tear resistance) to resist wind, hail, frost, and handling; Thickness ranging from 45 to 200 μm ; High impermeability to oxygen to achieve full anaerobiosis; Physical strength properties to maintain over a long time period (more than 1 year) under natural rain- and sun-exposure; UV protection (having different degrees in relation to the latitude); and Cost effectiveness without compromising necessary quality.

The multilayer, coextrusion blowing technologies currently used for plastic film manufacturing, using oxygen barrier (OB) polymers in combination with LDPE, allow greater oxygen impermeability otherwise the same level of anaerobic conditions that can only be achieved by LDPE films thicker than 2,000 μm . The plastic covering methods of silages are single plastic film (one step cover) to two layers (two steps cover) with a thin new plastic traditional PE film close to the silage mass and a thicker film or net to protect the under sheet from physical damage (wind, birds, rodents, cats, hail, etc.) and from UV damage. In two step cover, the sheet being close to the silage helps to achieve best OB.

For one step cover in horizontal silos, the traditional LDPE film of 80–200 μm thick, 4–18 m width having black, green, white and their combinations are used to achieve oxygen permeability of 890–3,550 at 23°C and 1 bar ($\text{cm}^3/\text{m}^2/24\text{ h}$). For lower oxygen permeability, oxygen barrier film (OB; LDPE-PA; 150–400) and high oxygen barrier film (HOB; LDPE-EVOH; 9–19) with 80–200 μm thickness and 4–8 m width having white/black color are generally used. In two step covers, above listed three films having same widths, 40–50 μm thickness and transparent yellow color are generally used that yields oxygen permeability of 4550–3550, 150–400, 10–19 at 23°C and 1 bar ($\text{cm}^3/\text{m}^2/24\text{ h}$), respectively. The open net and anti UV net for second cover in two step are HDPE polymers, 26–220 g/m^2 and 190–300 g/m^2 thick, green/black color to protect under-sheet from damage and UV rays (reused 4–7 years),

respectively. The silo wall is covered with LDPE film having 75–150 µm thick, 2–6 m width, black, white, black/white colour to protect walls from corrosion, water and oxygen permeation (Borreani and Tabacco 2017).

Storing silage in wrapped bales has become a very popular technique due to its less weather-dependence and provides wider flexibility in ration formulation. The bale silage technique is characterized by its unique individual package storage system that usually consists of wilting forage to around 400 g DM/kg, baling and then wrapping it with a stretch polyethylene (PE) film. Traditionally for bale wrapping, PE is used due to its suitable mechanical properties and low costs. Most plastic films for stretch-wrap silage production are coextruded LDPE that are 25 µm thick before being stretched by 50% (original length of 0.50 m becomes 0.75 m after stretching) during application to the bale. The plastic film is stretched, by means of a stretching unit fixed to a bale wrapper, and then wrapped around the bale. Four to six layers of PE are usually applied in 2–3 subsequent and complete rotations of the bale, with an overlap of 50% between the layers (Lingvall 1995).

The silage systems without a structure have proven to be a good alternative to bunker or tower silos for forage conservation (Savoie and Jofriet 2003). Nowadays, the popular storage system on a large number of farms is bag silo wherein crops are pressed using machine into PE tubes made of three layers of coextruded PE having 30–90 m length, 1.8–3.6 m diameter, 150–250 µm thickness. The use of bag silo is growing rapidly due to low cost, flexibility of storage capacity, possibility to store outside for a period of up to 2 years and its ability to segregate forages on the basis of their quality (Muck and Shinnars 2001). The latest plastic film technologies, i.e. blown coextrusion with polyethylene are able to greatly improve film impermeability to gasses (O₂ and CO₂). However film containing PA or EVOH is 30–50% more costly than film made of LDPE alone (Borreani and Tabacco 2014).

1. EVOH-coextruded barrier films such as the seven-layer structure PE/PE/Tie/EVOH/Tie/PE/PE have permitted oxygen impermeability to < 10 cm³/m² × day at standard conditions, without compromising the high mechanical performances of the PE-based films.
2. Another polymers used for coextrusion with PE is PA, which have good thermal stability and an oxygen permeability that is about 30 times greater than that of EVOH.

Later, OB films are tried to increase oxygen impermeability of the plastic films that has an effect on reducing the top spoilage losses, yeast count and to increase aerobic stability of silage than silage stored under a conventional PE film. The HOB film was made by coextruding a layer of a special grade of EVOH between two layers of PE linked to two tie layers in a five-to-seven-layer coextruded film. The EVOH layer improved the oxygen impermeability of the HOB film by about 10-folds, compared to the first generation of OB films.

Mater-Bi (MB) is a bioplastic which is a starch-based polymer (first completely biodegradable and compostable biopolymer ever invented and is blend of at least 50% starch and a synthetic hydrophilic, degradable polyester) can be utilized to produce bioplastic films of different thickness suitable for covering silage (Borreani *et al.* 2010). The alternatives to biodegradable plastic films to cover silage, is biodegradable coatings such as straw, apple pulp, or food industry waste, have been explored and suggested to replace PE films, however, these materials have been unsuccessful in forming a stable barrier against air and the environment for periods not more than 30 days. Borreani and Tabacco (2014) compared the standard 120 µm thick black-on-white PE film with two different 120 µm thick milky-transparent Mater-Bi biodegradable plastic films, viz. MB1 (blown film processing, monolayer) and MB2 (Three coextruded layers of MB to improve mechanical properties and stability) were used to produce the silage bags and reported that MB2 performed more consistently than MB1 in terms of good silage quality even in the uppermost part of the silage close to the plastic film up to 170 days of conservation, with similar results to those obtained with the PE film indicating the possibility of successfully developing a biodegradable cover for silage for up to 6 months after ensiling.

Silage bags commonly produced by Indian manufacturers are made of unique combination of advanced polyolefins which provides strength, softness, UV-resistance and low creep. These bags are transparent, white coloured whose outer layer is made of PP and inner layer is made of liner. These bags offer an easy, safe and economical way for temporary storage of mass, grass, grain and other products, allowing for optimal fermentation conditions and preservation of their nutrient value due to the tightness and lack of air inside them, even when the stored product contains up to 25% humidity.

Advantages of silage bags

- The weight of silo bag ranges from 2–5 kg, making them to handle easily.
- Silage bags are stackable, thereby saving on storage space and enable landless farmers to use silage.
- The capacity and dimensions are custom made depending on requirement of customer. The common capacity is 50, 100, 200, 500, 1000, 5000 kg.
- The labour requirement is very low, i.e. 1–3 persons can fill the bag.
- Silage bags have excellent retention of adequate moisture and pH as well as the nutritional value of the silage completely.
- The wastage of silage in bags on account of mud contamination is completely avoided.

In addition, the plastics are being used in fodder production in the form of plastics in azolla pond cultivation, plastic mulch in green fodder production, plastic poly bags for raising saplings in fodder nurseries, etc. Readymade plastic ponds of 8'×4'×1' size are available in market for cultivation of azolla as fodder. Ponds dug into the earth

and lined with polyethylene sheet can also be used for azolla cultivation. As we know that the use of plastic film has offered tremendous scope as lining material and provides an effective impervious layer, thus prevents water loss due to seepage and also the growth of weed roots in the bottom of the pond is prevented. Agri-film is available in thickness ranging from 100 to 250 microns and width ranging from 4 to 12 m. Low Density Polyethylene (LDPE) film (Agri-film) has got excellent water barrier properties, very good blend of physical properties like tensile-impact strength coupled with good weather ability and chemical resistance properties hence can be used as convenient and economical lining material for azolla ponds. Generally azolla pits are covered with shade net to provide shaded light in the pond. Azolla is a floating fern and can easily be grown in plastic lined ponds.

Plastic sheet can also be used as mulch to suppress the weeds and conserve water in crop production. It was initially tried at the agriculture farm of ICAR-CIRG for cultivation of *Moringa oleifera* as fodder crop for goat feeding. It has been found very effective in control of weeds. Photodegradable and biodegradable mulches should be preferred due to environmental issues. Biodegradable plastic films are converted through microbial activity in the soil to carbon dioxide, water, and natural substances. Starch-based polymer blends can degrade when exposed to bioactive environments such as soil and compost. Due to availability of biodegradable materials from petroleum and natural resources, opportunity for using biodegradable polymers as agricultural mulch films has become more viable.

Protected moringa nursery was tried using plastic bag at ICAR-CIRG farm and was found helpful in controlling practical problem of peacock, monkey and wild boar damage in fodder fields. It is cost effective, convenient and gives better survival of plants and also helps in gap filling in the main field of moringa cultivation. Nursery can be maintained by planting soaked seeds directly in the soil filled smaller black colour poly bags of 23×13 cm size and thereafter these bags are filled with the potting mixture leaving one cm at the top of the bag.

Plastics in livestock farm operations

The plastics are extensively used in dairy farms and dairies in the form of equipment's and tools and readily available in market are milk cans, milking machines and tubings, brushes, crates, other dairy equipments like unbreakable plastic wheel barrow, air circulator wall mounting fan, glove, feeding and watering troughs, etc. Similarly, the plastics used, in other livestock species such as sheep, goat, pig and poultry rearing have too much importance when comes to feeding and watering systems, flooring systems, etc especially its role become inevitable when we prefer Hi-tech Farming or Automation in farm operations. The plastic based silage bags, milk cans and other farm utensils like ear tags, sickle handles, broom stick, tree guards, dunggi, hoof knife/trimmer, etc may also prepared using PVC pipes and other plastic materials.

Milk crates are square or rectangular interlocking boxes that are used for transportation of milk and other products from dairies to retail establishments.

Glove is used to massage the animal, rectal examination of bovines etc.

Washing brush is used to clean the animals. It has dual side, one side is for cleaning and the other side is for massage. Dual side brush and glove increases the blood flow, improve the health and increases the milk in dairy animals.

Dip cup is used to clean the teat of cow/buffalo, before and after milking to prevent infection.

Ear Tag is used for animal identification, i.e. marking is done to identify and track specific animals for verification of ownership, bio security control, and tracking for research or agricultural purposes.

Ear Tag Applicator is used to apply tags on ear of livestock and other animals.

Hoof Knife is used for hoof trimming in livestock, sole abscesses, hairy tack, soft toe, and other hoof diseases.

Feeding Bottle is used to milk feeding to orphaned young ones of livestock like calf/kid/lamb, etc and mothers having low/no milk due to health problems.

Milking Pail is made of polycarbonate plastic material with mostly 30 litre capacity. This pail is safe for food, has double graduation (kg and lb), metal handle to carry and can be used to check each individual cow's milk yield and is also used in mobile/portable milking machines.

Plastic cattle weaner is used for discouraging milch animals and calves from sucking at each other and is applied as nose ring.

Foremilk Cup is used for quick detection of clinical mastitis through flakes, blood clots and milk texture during milking.

Semen straws and AI/ET sheaths are made of PVC materials. The mini (0.25 ml) and medium (0.50 ml) straws are used for semen packaging and sheaths are used in livestock AI/ET programme.

Feeding and watering appliances in livestock farm can be prepared cost effectively by using locally available plastic materials. The 9" PVC pipes are cut in such a way that it can be used as plastic feeder and waterer for kids/lambs/poultry by closing both ends using plastic PVC coupling. This plastic feeder and waterer can be fixed using wooden poles or iron hooks or iron stands. The cost effective plastic feeders and waterers can also be made by using plastic barrels of different capacities with or without using supporting frames. The customised plastic feeders and waterers suitable to fix directly on the partitions made in the livestock farms are also available in the market. At ICAR-CIRG, the rectangular plastic feeder (CIRG-RP) for adult goats using FRP sheets and PVC pipes has been developed to have light weight and are cost effective as compared to conventional feeders made of iron. Feeders and waterers are extensively used in large commercial poultry farms like automatic feeder (gallinas, pollos) for accuracy in feeding as per production levels.

Plastics in milk production and its products

The role of plastics in livestock sector is enormous in terms of milk and meat products' packaging and marketing. Most of the dairies in India distribute milk by non-returnable containers like polyethylene pouches, which is the common packaging material for milk and are single strip packages, very light in weight, less loss during filling and less storage and transport space is required as compared to glass bottles and paper board cartons like tetrapak, tetrabrik and purepak. Polyethylene is the most widely used packaging material in India due to its low cost and easy availability and these thermoplastic films can be fabricated into bags (Kumar 2009).

Bureau of Indian Standards (BIS) prescribes requirements and testing of polyethylene pouches for packing of pasteurised liquid milk in 1 and 0.5 litre capacities in IS:11805:1986. As per this standard, milk pouches should be made from virgin polyethylene (LDPE, linear LDPE-LLDPE, HDPE or Ethylene-Vinyl Acetate Copolymer- EVA) for meeting the food grade requirements. Initially, LDPE film was used but now LLDPE is preferred choice for milk packaging. More recently, Octane and butane-based LLDPE are used due to less leakage (1–5% in LDPE, 0.6% in LLDPE film), less area of pouches, etc. The revised BIS standard (2003) for milk packaging suggests that food grade virgin polyethylene (LDPE, LLDPE or a blend thereof) as well as coextruded 50:50 blend of LDPE with melt flow index (MFI) of 0.5 and octane LLDPE with MFI of 1 is the common film in vogue. The specification IS:11805 specifies thickness (85 µm for 1 litre and 75 µm for 0.5 litre pouches), yield strength (11.77 MPa and 8.33 MPa for the machine and transverse directions), elongation, dart impact strength and slip, tests on leakage and ink adhesion (Kumar 2009). Depending upon the requirements for various milk products, storage conditions and shelf life in room/refrigerated conditions and required sensory qualities of the products, LDPE, LLDPE, HDPE, paper, Aluminium foil, MXXT cellophane, MetPET, tin, etc. are being used in various combinations and thickness. For example, Khoa sample packed in parchment paper and HDPE plastic film were found satisfactory up to 5 days in 37°C, up to 12 days in 8°C and up to 75 days in –20°C.

Milk pouches used at homes are made from virgin food grade plastics and are largely recycled through informal recyclers such as scrap dealers. For 500 ml of milk requires 5 g of plastic packaging but the same quantity of milk will require 500 gm of a recyclable glass bottle under alternative mechanism (Wadke 2018). Therefore, the milk packaging in bottles has disadvantage over plastic pouches that it increases the transportation costs; huge water is required for steam cleaning and occurrence of breakage. An estimate indicated that approximately 15,000 tonnes of plastic waste is generated every day across India, out of which 9,000 tonnes is collected and processed and 6,000 tonnes remains uncollected and poses hazardous impact on the environment. Though the government is insisting plastic manufacturers and dairies to set up a mechanism for

recycling milk pouches, both sectors deny to take up the responsibility under the Extended Producers Responsibility (EPR) rules (Wadke 2018).

Plastics in meat and egg production and its products

The most common packaging material for fresh meat cut is polystyrene foam or clear plastic trays over wrapped with a transparent film which can be stored at 0°C for 10 days, however it can retain desirable bright red meat color up to 5 days only (Matche 2009). The fresh meat can be wrapped for considerable period using cellophane coated with nitrocellulose on one side and uncoated side is kept in contact with meat. Another grade of cellophane coated with PE on one side can be used for irregular shaped meat. The plastic films used for wrapping meat should have excellent optical properties. Among the synthetic plastic film hydrochloride, LDPE (25 µm), highly plasticised PVC films LDPE (18 µm), biaxially oriented polystyrene film can be used for meat packaging.

For vacuum packaging of meat, suitable plastic film should have high resistance to transmission of gases and water vapour with perfect seal and good mechanical properties. The typical materials which are in-use for vacuum packaging are co-polymer-coated cellulose/PE film laminate or polyester/PE film laminate or nylon/PE film laminate (all PE inside), laminates of plastic films with aluminium foil, polyvinylidene chloride (PVDC copolymer film, EAA/Saran/EAA laminate, nylon/EAA laminate, PVDC/polyester/ PVDC/PE laminate, LDPE/BA/nylon/BA/LDPE (Matche 2009).

The four basic methods in vacuum packaging of meat are given here.

Shrink bag: Meat is placed in a shrinkable barrier bag of EVA copolymer/PVC/PVDC copolymer/ EVA copolymer/ polyamide as the barrier layer and an ionomer as the inner and outer layer and then evacuating the bag prior to sealing. Then it is sealed with heated jaws and shrink bags are then heat shrunk in water at 90°C. After shrinking, bag conforms closely to the meat and produces the tight vacuum pack.

Non-shrink bag: Meat is placed into a preformed plastic bag and kept in evacuated enclosed chamber. After reaching the predetermined pressure, bag is sealed using heated jaws. Typical bag constructions consists of laminates/co-extrusions which include polyamide or PET as outside layer (for strength and good oxygen barrier) LDPE ionomer or EVA copolymer as inside layer (for good moisture barrier and for easy heat sealing) with the typical structure as ionomer- polyamide-EVA copolymer.

Thermoforming: The deep trays are thermoformed in-line from a base web of plastics. Meat is placed in trays and an upper web of plastic is heat sealed under vacuum to form a lid. Generally materials used for thermoforming are laminates of polyamide, PET or PVC, sometimes with PVC/ PVDC copolymer coating and heat sealing layers such as LDPE, EVA copolymer or ionomer. This packaging is well suited to hot boned, pre-rigor meat which is difficult to pack in bags.

Vacuum skin packaging: The meat portions are skin packed in a barrier film material, the top web of which is softened by heating before applying a vacuum and sealing. The soft film moulds itself in to the shape of meat to give a skin-tight package for maintaining anaerobic conditions.

Frozen meats are packed in a material which is relatively permeable to oxygen to maintain bright red colour of meat. Ionomer plastic film can maintain bright red colour for at least one year, if meat is stored in dark at -20°C . The frozen, restructured meat products have traditionally been packed in bags, pouches, trays, overwraps, plastic coated paper board, with polyolefins being the most common materials used. The packing materials should contain appropriate plasticisers to have mechanical properties to withstand sub-zero temperatures. Vacuum skin packaging is also used for frozen, restructured meat products.

Thermo-processed meats are processed at above 100°C with the help of pressure to prepare commercially sterile meat products like nuggets, sausages, patties etc for short term storage at 4°C for 10–12 days using PE, PP, PVDC, rubber hydrochloride, etc. The meat products like meat soups, meat gravies, corned beef and pork, chicken curry, etc are stored for long term at room temperature for minimum one year using retort pouches made of composite films especially film-foil-film laminates as follows.

- Outer plastic film of polyester, polyamide or oriented PP (for support and physical strength)
- Middle layer of aluminium foil (for excellent barrier properties)
- Inner layer of PP (for head sealability)

For dehydrated meats, metal/foil/plastic film laminates compressed bars of dehydrated minced meat with inner cellophane and outer paper/aluminium foil/PE laminate wrap reported to be stable for one year. Flexible pouches are most suitable for vacuum and modified atmosphere packaging consists of polyester/PE/Aluminium foil/PE or cellophane/PE/Aluminium foil/PE laminates. The packaging of dressed whole poultry birds/halves/cut up parts for retailing and early use can be done in plastic films like PE, PP, PVDC, rubber hydrochloride, nylon-6 films of 38–50 μm (Matche 2009). For bulk packaging of meat products, plastic crates have become popular as bulk containers due to their toughness, light weight, dent resistance and ease of stacking and handling.

For packaging of eggs, moulded pulp filler flats or plastic filler flats of each containing 30 eggs; folded paperboard cartons with shrink film overwrap of PE, PVC or PVDC; expanded polystyrene foam egg cartons or trays can be used.

Plastics in livestock shelter

In the era of climate change, livestock production is shifting from rearing for livelihood purposes to commercial purposes. Accordingly, automation of modern shelters are emerging with sophisticated facilities like raised plastic floor with pillars, automotive feeding and drinking system, customised feeders and waterers for easy fixing in partitions, weighing system with RFID identification and tracking,

milking machines, etc. is taking place in intensive meat and dairy farms on larger scale. Similarly, the tools used for various farm operations are also changing from traditional materials to durable materials like plastic materials. Though the application of plastics in agriculture particularly crop sciences for protected cultivation is in practice since few decades, its use in livestock production is limited and the plastics utility in animal shelter and its practicability under Indian conditions are yet to be explored. Therefore, through AICRP on PET project, the plastics in goat shelter are being investigated initially for its effect on goat and yak production, health and welfare.

The importance of shelter for profitable livestock rearing plays an inevitable role in large scale commercial enterprise especially on intensive rearing system. The modern livestock shelters address the two foremost component of shelters, i.e. floor and roof that affects comfort and productivity. Sutherland *et al.* (2017) reported that goats prefer to use different flooring types depending on the behaviour they are performing hence, multiple flooring options are better to meet their needs in commercial systems. Research on alternative flooring and roofing solutions in livestock production are limited, probably because of the higher initial cost of raised floor in livestock shelters. However, the initial high cost shall be balanced by use of slatted floor on shelters through man power saving in daily cleaning in conventional soil floors (Ramachandran *et al.* 2017, 2019), hence on large scale commercial livestock farms, slatted floor shall be used for hygienic production of livestock products for health conscious consumers. The conventional slatted floor using bamboo and wood demands frequent recurring expenses, leg stuck problems, etc. To overcome these disadvantages, plastic slatted floor materials shall be tried due to its long life and are extensively used for commercial sheep, goat, pig and poultry farms for hygienic production of milk, meat and eggs.

Plastic slatted floor materials are available now-a-days which can be used as floor materials in livestock farms. In addition, these floor materials can also be used as bedding materials at lower heights to replace conventional bedding materials like grasses in small livestock species, viz. sheep, goat, pig as well as poultry. The plastic floor materials can also be used in smaller sized kids' hutches, enclosures in kids' nursery for giving more welfare to new born kids/lambs in livestock farms. Normally, the height of raised floor is recommended at 5 feet from the floor. The perforated plastic floor materials of $2' \times 1'$ size are available in two grades, viz. grade-A and grade-B quality that costs about ₹ 160 and ₹ 180/square feet, respectively. These plastic slatted floor materials can be installed either conventionally over angle iron and flat iron supporting structures or fibre reinforced plastic (FRP) support structures. The approximate cost of plastic slatted floor materials with FRP support structures is about ₹ 400–450/square feet.

Though plastic slatted floor manufacturers are aggressively marketing, the scientific reports on its effect on the production performance and welfare are not available

in the literature. Few studies on flooring preferences indicated that plastic slats may be acceptable options in addition to straw bedded floors (Boe *et al.* 2007, Muir *et al.* 2013, Sutherland *et al.* 2017). The provision of plastic slatted floor in shelter resulted in similar growth in three goat breeds (Ramachandran *et al.* 2020) and lambs (Kumar *et al.* 2019) as compared to soil floors and further indicated the suitability of plastic floor in small ruminant shelters even in hot dry season of the year in semi-arid conditions based on physiological responses and blood biochemical parameters in kids and lambs. Antil *et al.* (2019) explored the use of plastic slats as bedding materials at 6" height from floor for protecting kids from cold stress and reported that kids experienced similar growth and welfare and lower dirt score as compared to kids raised on soil floor and rubber mats. However, Muñoz-Osorio *et al.* (2017) reported that fattening lambs housed in raised slatted floor cages were heavier (ADG 306.5 ± 2.69 g) than those raised in floor pens (ADG 269.4 ± 4 g).

The use of plastics in roofing structure of animal shelters is possible both in cost effective shelter in small holder production system as well as in commercial livestock shelters. The roofing materials generally used in cost effective shelters is thatch material, the life of which is about 1–2 years only and needs recurrent repair and replacement. To increase the life of about 3–4 years in thatch, 200–300 GSM thick polyethylene can be used to cover the thatch roof which protects thatch from rain waters. In commercial livestock shelters, Fibre Reinforced Plastics (FRP) sheets (plain/corrugated) in different dimensions (can be customised) and colour (green, blue, transparent, orange, yellow, etc) can be used as alternate roofing material. Normally, corrugated sheets of plastic sheets of 3–5 mm thickness are commercially available in market that can replace the corrugated cement sheet for roofing. The preliminary study on plastic roofing in goat shelter indicated that provision of FRP roof in place of cemented sheet roof may not be beneficial in increasing milk yield of does during winter season (Ramachandran *et al.* 2018). Further, the expanded polyethylene (EPE)/ expanded polyurethane (EPU) foam sheets of different sizes or sheep wool are sandwiched between FRP sheets on one side and aluminium sheets on other side as roofing materials in shelters to have desired microclimate inside the shed especially during winter season for protecting new born calves, kids, lambs etc (Singh *et al.* 2016, 2017, 2018).

The animals are protected from winter with the use of gunny bags/jute bags/tarpaulin and 4" thick thatch panels on long side of the shed conventionally. However, these conventional winter care measures in livestock farm can easily be replaced with plastic sheets and use of panels prepared from expanded polyethylene (EPE) foams/styrofoams etc for replacing thatch panels. Sliding plastic panels, sandwiched panels, etc can also be used to maintain desired minimum temperature during winter nights. In addition, using these sandwiched plastic panels, portable and light weight enclosures shall be fabricated to protect

young livestock from cold stress either inside the shelter or even in open paddocks as temporary enclosure (Ramachandran *et al.* 2019). This portable plastic enclosure using sandwiched panels can also be used to protect kids and lambs from inclement weather in higher altitude in migratory production system.

Conclusion

Application of plastics or plasticulture have important role in enhancing overall production of livestock. Plastic is wonder material for livestock industry. Most popular derivatives of plastics such as LDPE and PE have made significant impact in animal feed industry through silage preparation and conservation. Due to its good barrier properties, low cost with high strength and flexibility it has got maximum application in dairy industry for production, storage and transportation of animal or livestock products. Shelf life enhancement through packaging of animal products broaden its application. It has been evident from the recent intervention of Plasticulture under AICRP on PET that use of plastics in roofing, flooring, walls, etc. of animal shelters is possible both in cost effective shelter in small holder production system as well as in commercial livestock shelters. However, the plastics used for agricultural and livestock production purposes are not covered under single use plastics (SUP) and its proper disposal and recycling is the need of the hour and utmost necessity in daily life to protect environment in the era of climate change. Application of plastics in livestock also opened door to opportunities and scope of agribusiness through supporting ventures like packaging, transportation, housing, silo, etc. by creating demand in this area. Extensive research is required in material development such as composite materials for livestock area and finding new area of application like animal handling, operation, etc.

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