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Agricultural Waste Management

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AGRICULTURAL WASTE MANAGEMENT

PREAMBLE

In India about 1566 million tonnes of agricultural residues/byproducts/wastes of different kinds (field and horticultural crop residues, agro-processing residues, animal dung, poultry excreta and processing wastes of animal, poultry and fisheries sectors) and about 48.50 million pieces of hide and skins are produced annually. The estimated values of these byproducts/wastes is approx, Rs. 2,35,000 crores annually calculated on an average rate of Rs 1500/- per tonne. A major portion of these residues/byproducts/wastes are presently being used either as cattle feed, incorporated in the soil as such, converted into farm yard manure and applied in the fields. Only small portion is used for energy purposes either through bio- methanation or bio-gasification routes. The energy generated is used either for thermal application or for decentralized power generation or for both. Small quantities of crop residues are also being used for thatching purposes in rural areas, packaging and in paper industry. However, about 15 million tonnes of rice straw is being burnt in Punjab, Haryana and Western UP, and about 5 million tonnes of cotton stalks are being burnt in Gujarat and Maharashtra. Similarly other crop residues such as wheat straw, hardy portion of soybean straw etc are also being burnt in small quantities. If such byproducts/wastes are managed properly and proper value addition is done, they will give better economic returns, will pose much less environmental and health hazards and will also generate more income and employment opportunities.

Keeping in view the above facts, a Brain Storming Session was organized in the premises of the National Academy of Agricultural Sciences, New Delhi during October 23-24, 2009 to deliberate on the present status and technologies available for efficient management of different types of agricultural by-products and wastes, identify future researchable issues, identify environmental concerns, make appropriate recommendations and strategies for future promotion of technologies for efficient management of such by-products and wastes for their best utilization and economic returns. Thirty scientists, renowned and experienced in their field of specialization attended the Brain Storming Session. They deliberated on following important aspects.

- Assessment of total availability of by-products/wastes including that of agro-processing from field crops, horticultural crops, animals, poultry and fisheries—region and season wise.
- Assessment of prevalent and potential uses of agricultural by-products/wastes for feed and fodder, paper industry, particle board, packing material, mushroom growing, building material, soil organic matter amelioration and preparing of FYM, as domestic fuel, and for generating biogas and producer gas for energy purposes.
- Availability of efficient systems and equipment and their economics.

- Fortification, densification/ briquetting/ pelleting, handling, transport and storage of crop residues as animal feed and their economics.

- Densification of crop and agro-processing residues into low and high density briquettes for combustion and gasification in domestic cook stoves, boilers and gasifiers for thermal applications and power generation.

- Biomass to energy conversion routes

- Characterization of crop and agro-processing residues – physical, chemical, thermal proximate analysis, elemental analysis, summative analysis)

- Efficient method of compost preparation, its handling, transport and application in field.

2. ASSESSMENT OF ANNUAL AVAILABILITY OF DIFFERENT TYPES OF AGRICULTURAL RESIDUES/ BYPRODUCTS AND WASTES AND THEIR PRESENT USES

No reliable data are available on the total annual production of agricultural wastes , their uses and surpluses which could fruitfully be utilized for other uses. Based on the grain to straw ratio and main product to byproduct ratio of different crops, an estimate has been made about the total production of different types of crops and agro-processing byproducts, their present uses and surpluses available using the 2008-09 agricultural production data published in the Agricultural Statistics at a Glance 2009 published by the Directorate of Economics and Statistics, Ministry of Agriculture, Government of India and Indian Horticultural Database 2009 published by National Horticulture Board, Ministry of Agriculture, Govt of India.

2.1 From field, horticultural and plantation crops

Annual production of agricultural byproducts/wastes of field crops are estimated at 679 million tonnes (Mt) out of which surplus available for processing is estimated at 233 Mt (Appendix I).

As regards fruits the estimated production of wastes etc. is at 83.34 Mt out of which 41.67 Mt is available as surplus (Appendix II). The annual production of wastes etc for vegetable crops is estimated at 173 Mt out of which 86.50 Mt is available surplus. The annual products of wastes etc. from plantation crops is estimated at 7.0 Mt out of which 5.50 Mt is available surplus. The available surplus from mushroom, honey etc. is estimated at 0.001 Mt. Thus total available surplus from wastes from horticulture is estimated at 134 Mt.

Some of the economic uses of surpluses of important agricultural byproducts and wastes from field and horticultural crops are given in Table 1.

Table 1. Some economic uses of surplus agricultural byproducts and wastes from important field and horticultural crops

Item	Future uses
Rice and wheat straw	Paper industry, mushroom growing, biogas production, low and high density briquettes for energy purposes, alcohol production through enzymatic activities of cellulosic material, vermin- compost.
Cotton, jute, pigeon pea, rapeseed and mustard stalks	Briquetting for use as domestic and industrial fuel, particle board.
Spent maize cobs	Briquetting for fuel purposes
Sugarcane Bagasse	Animal feed, briquettes to be used as domestic and industrial fuel)
Banana stem	Fibre for making clothes, baskets and other products; some quantity mixed with cow dung for biogas production
Banana Pseudo stems	Fibre, chemical extraction, juice has high potassium
Peal of citrus and oranges	Cosmetic products
Cashew nut shell	Oil
Cashew nut apple	Fenny-alcohol
Safflower petal	Medicinal use
Mango stone	Vitamins, protein
Lichi peal	Animal feed
Areca nut leaves	For making plates
Lac byproduct	Lac dye

2.2 From waste lands, road-sides, forestry and agro-forestry.

The availability of agricultural residues/wastes from these areas are mainly in the form of biomass, wood, minor forest fruits etc. In 2001 the biomass waste from these sources were estimated as 204 million tonnes as per details given in Appendix III.

The biomass/wastes available from the above sources are presently being utilized by the people below poverty line who collect / cut these from waste lands for use as firewood and fodder. Many a times it is collected by the landless people and sold in the market.

2.3 From livestock and poultry

2.3.1 Excreta/ Dung

India has a huge livestock population of over 485 million (2003 Livestock census) consisting of 185.18 million cattle, 97.22 million buffaloes, 61.47 million sheep, 1.35 million pigs, 0.75 million horses and ponies. 0.18 million mules, 0.65 million donkeys, 0.63 million camels, 0.065 million yaks and 0.278 million mithuns. Such a huge animal population has variation in species composition in different states and depends upon grazing and stall feeding based on crop residues from degraded rangelands and forests

The wastes available from animals can be categorized in to two types:

i) Cattle yard waste such as excreta, urine, leftover fodder, bedding and mixed soil.

ii) Animal by- products such as hides, skins, bone, ruminal contents, horn, hoofs, blood, meat, other tissues, glands etc.

As per Livestock census 2003 there were 489.012 million poultry birds in India. Similar to livestock, the wastes available from poultry are of two types:

i) Poultry droppings.

ii) Poultry dressing—blood, intestinal tract, head, legs and feathers.

Although reliable data on the total annual availability of animal and poultry wastes are not available but based on the average quantity of dung and excreta produced by them, as shown in Appendix IVa, annual availability of dung and excreta from these sources have been estimated as 369.50 million tonnes as shown in Appendix IVb.

Out of the annual available dung and excreta about 70% can be collected. The dung produced by animals during grazing and excreta of back yard poultry is difficult to collect. Thus the available dung/excreta for use is likely to be about 259 Mt (DM Basis).

The traditional method of utilization of dung and excreta is application in the field as FYM, dried as patties or dung cakes to be used as fuel. Modern method of its utilization is proper composting, vermi-composting and then application in the fields as FYM. Some quantity is used for biogas production, which is used for heating and lighting. The slurry produced from the biogas units is applied in the field as manure.

The main sources of animal waste are slaughter houses, cattle yard, fallen animals, tannery, poultry dressing and fish offlets.

2.3.2 Slaughter House Waste

There are two types of slaughterhouses operating in the country, organized and unorganized along with illegal slaughtering in many parts of India. The data on the availability of raw material is mostly available from legal slaughtering taking place in the organized slaughterhouses. Precise estimate of number of animals slaughtered annually is not available.

The break-up of various types of tissues which are obtained after the animal is slaughtered, is given in Table 2, while uses of different types of slaughter house waste are given in Table 3.

Table 2. Breakup of different types of tissues of slaughtered animals

Sl.No.	Product	Percent of body weight
1	Hides and skin	5-6
2	Bone	15-30
3	Ruminal contents	8-10
4	Horns and hoofs	1-2
5	Blood	4-6
6	Meat	35-40
7	Fat and soft tissues (Heart, kidney, stomach, esophagus, liver, intestine etc.)	lungs, 10-15
Products at sl. No. 1-5 are not eatable while 6 and 7 are eaten only by certain group of people		

Source: Kumar, Mahendra and Thyagrajan, G. (1989). Utilisation of animal byproducts and the export potential. From Book entitled "Animal Productivity" published by Oxford and IBH Publishing Co. Pvt Ltd. New Delhi.

Table 3. Different Uses of slaughter house waste

Item	Present uses
Blood	Blood meal, haematinics, used as adhesive in plywood, in cheese making, foam rubber, intravenous feeding and medicine, in food as lecithin
Animal fat and oil	In food, cosmetics, highly allergenic
Hair/Bristles	In some blankets, mattresses, brushes, furniture etc.
Pancreas	Insulin
Bone char/meal	Used in bone china, in some tooth paste, bone meal, Di Calcium phosphate gelatin
Hide and skin	Leather, shoes, Wallet, Hand bag, leather suitcase, belt, furniture etc.
Offals	Catgut, intestine of horses and sheep etc as surgical sutures, stringing tennis racket and musical instruments
Heart, feet, hooves,	Used as fertiliser
horns and intestinal content	
Meat Scraping	Meat meal used for animal feed

Assuming that 5% of the animals are slaughtered every year the total production of annual availability of wastes from slaughter houses would be about 24.25 million pieces of hide and skins and about 10 Mt of other wastes.

Another important source of animal by products is fallen carcasses. Assuming mortality rate of 5 per cent for large (cattle, buffaloes, horses & ponies, mules, camels donkeys, yaks and mithuns) and 5 per cent for small (sheep, goats and pigs) animals, about 24.232 million fallen carcasses would be available annually at 2003 level of animal population which will yield approximately 24.232 million pieces of hide and skin and about 7.147 Mt of bone- cum- meat meal, tallow, ruminal content and hoofs & horns as shown in Table 4.

Table 4. Estimated production of byproducts from fallen carcasses

Byproduct	Estimated availability
Hide and skins	24..25 million pieces
Hoofs and horns	0..286 Mt
Ruminal content	1.141 Mt
Tallow	0.858 Mt
Bone and meat meal	4.862 Mt
Total	**7.171 Mt + 24.25 million pieces of hides and skin**

The NPK content of fertilizer from animal waste are quite high as shown in Appendix V.

2.3.3 Fisheries waste

The growth of fisheries sector during the last about 50 years has been quite fast. The production of fish, both, inland and marine, which was about 7.52 million tones in 1956 increased by ten folds and was 71.27 Mt in 2007-08 (29.20 Mt marine fish and 42.07 Mt inland fish). The Fish being a perishable item has high losses at different levels, which could be of the order of about 40% of the total catch. Thus about 28 Mt of fish are lost/ spoiled and are not suitable for human consumption. Industrial fish processing for human consumption yields only about 40% edible fish and remaining 60% is thrown away as waste. By adopting improved technologies for harvest and post harvest operations and value addition these losses could be greatly minimized and value added products will give more returns to the fishermen and fish processors.

Under NATP sponsored Mission Mode Project during 2001-04, assessment of harvest and post harvest losses of 7 commodities, namely, milk, meat, egg & poultry, oilseeds, wool, marine and inland fish was done under the leadership of Indian Agricultural Statistics

Research Institute, New Delhi. The Central Institute of Fisheries Technology, Cochin, which is a premier Institute working on fishing and fish processing technology was chosen as the Nodal Institute for the assessment of losses in fisheries sector. Their detailed study of harvest and post-harvest losses of inland and marine fisheries showed that there were losses at different stages of handling the fish which are given in Appendix VI and VII. The reasons for those losses are also given in the Appendix VI and VII.

Studies conducted at CIFT Cochin has shown that in processing of different types of fish in the processing industries 10-70% waste is generated as shown in Appendix VIII.

Fisheries wastes can be used as manure or converted into several value added products like fish meal, fish silage, fish hydrolysate, surgical sutures from fish gut collagen, isinglass, leather, insulin, gelatin and collagen, chitin, chitosam, glucosamine hydrochloride and glocosamine sulphate.

2.4 Total agricultural residues/ wastes/ byproducts

Total annual production of agricultural crop residues/byproducts and wastes from different sources are estimated as 1566.37 million tones + 48.50 million pieces of hide and skins as given in Table 5.

Table 5. Annual production of different kinds of agricultural residues/byproducts and wastes

Type of waste	Annual production in Mt
Crop residues from field crops	679
Crop residues from horticultural crops	268
Road side/ forestry and social forestry waste	204
Animal dung/excreta on DM Basis	9.50
Slaughter house waste	10.00+ 24.25 million hide and skins
Waste from fallen carcasses of animals	7.17 +24.25 million hide and skins
Fisheries waste	8.00
Total	**1566 + 48.50 million pieces of hide and skins**

Different types of agricultural residues, byproducts and wastes can be utilized more profitably by value addition and use of improved technology for their efficient utilization. The problem lies in their collection from scattered places, their handling, transport and proper storage.

3. CROP AND ANIMAL RESIDUES/ WASTES AS MANURE

While bulk of residues/wastes from field, horticulture and plantation crop will continue to be directly incorporated in soil, it is advisable to use these materials after proper composting/ vermi composting. Composting is a highly complex biodegradable process carried out by a diverse group of microorganisms capable of degrading simple and complex organic substances. A succession of microbial growth and activity among the bacteria, fungi, actinomycetes, yeasts etc takes place during composting, whereby the environment created by one community invites the activity of successor group.

Recycling of organic wastes by incorporating chemical amendments and bio-inoculums are the recent developments in the composting technology to manage voluminous wastes with economic advantages as well as environmental and social perspectives.

The factors affecting the composting process are carbon : nitrogen ratio, moisture, temperature, oxygen supply in the compost pile and micro-organisms like psychrophiles (low temperature microbes), mesophiles (Medium temperature microbes) and thermophiles (high temperature microbes).

For efficient recycling of bio-degradable organic wastes, composting technologies such as vermin-composting, phosph-sulf-nitro compost, microbial rich compost and p-enriched vermi-compost have been developed utilizing agro-industrial wastes, distillery effluents, press mud, poultry waste and are also co-composted with certain mining waste materials such as rock phosphate and pyrites for increasing the nutrient supplying potential of the compost.

FYM/compost management should aim at reducing the negative effects and maximizing the positive effects of manure. Scientific methods of composting and its mechanized handling and application should be popularized. Standards for good quality compost need to be formulated and adopted.

These aspects are beyond the scope of this policy paper which focuses more on uses other than manure. However, machinery aspects of handling manure are discussed below:

3.1 Mechanised collection, handling, transport, field application of animal and poultry byproducts and wastes

Farm/animal wastes are applied in the field either in solid form as FYM or in liquid form as urine, wash water from barns and slurry from biogas plants. For efficient utilization of the nutrients, these wastes should either be deep placed in soil or applied on the surface and immediately incorporated in the soil to avoid loss of nitrogen.

3.1.1 Manure spreader

For uniform application of FYM, different types of manure spreaders are commonly used

in advanced countries. In India also tractor operated manure spreader have been developed by some R&D organizations. They need to be properly evaluated, refined and popularized.

3.1.2 Slurry handling machine and applicator

Slurry handling equipment consists of two separate equipments. One for separating the solids from the slurry and the other for transport and application of liquid slurry in the field. A slurry applicator consists of a large tank mounted on a trolley with integral or separate arrangement for mounting tines for making slits in the soil where the liquid slurry is applied at desired depth and covered with soil.

Commercial machines are available in developed countries. They need to be imported, evaluated, adopted for Indian conditions and popularized through Front Line Demonstrations.

4. CROP RESIDUES/ WASTES AS ANIMAL FEED

Major part of the animal feed in India consists of crop residues with small amount of green fodder and concentrates. Poor ration results into poor health of the animals and low productivity. It is estimated that the present demand of feed and fodder for the livestock sector in India is about1650 million tonnes (1061 Mt of green and 589 Mt of dry fodder) which by 2020 will increase to about 1800 million tones (1134 Mt of green and 630 Mt of dry fodder). The scenario of feed and fodder requirement and their availability during 1995 to 2025 is given in Table 6.

Table 6. Requirement and availability of feed and fodder for livestock sector in India (million tonnes)

Year	Demand		Availability		Deficit as % of demand	
	Green	Dry	Green	Dry	Green	Dry
1995	373.3	421	947	526	59.96 (568)	19.95 (105)
2000	384.5	428	988	549	61.10 (604)	21.93 (121)
2005	389.9	443	1025	569	61.96 (635)	22.08 (126)
2010	395.2	451	1061	589	62.76 (636)	23.46 (138)
2015	400.6	466	1097	609	63.50 (696)	23.56 (143)
2020	405.9	473	1134	650	64.21 (728)	24.81 (157)
2025	411.3	488	1170		64.87 (759)	24.92 (162)

The present demand of concentrate is estimated as about 130.55 Mt and the availability has been estimated as 48.27 Mt. Thus there is a deficit of about 63.03 Mt of concentrate which is about 48.28% of the present requirement.

In view of the above situations first priority should be given for utilization of field and horticultural crop and agro-processing residues for utilization as animal feed and only surpluses beyond the requirement of animal feed should be utilized for other purposes.

For this purpose proper management practices should be adopted for collection, densification, fortification, handling transport and storage of feed and fodder for animals. Animal feed plants should be installed at important places in the production catchments to prepare Technically Modified Ration (TMR) for animals in the form of feed blocks which should be transported to fodder deficit areas and stored to be used at times of need.

4.1 Fortification, densification/ briquetting/ pelleting, handling transport and storage

4.1.1 Feed blocks

For increasing the nutritive value of straw the crop residue bales can be treated with anhydrous ammonia. The curing period could be 4-8 weeks. It could also be treated with Urea. GBPUAT Pantnagar has developed a urea treatment plant costing about Rs 65,000/- in which 216 bales in 6 layers (2m high) weighing about 5 tonnes are treated in one batch. Urea in the proportion of 5% of the weight of the bales is dissolved in water and sprinkled from the top of the bale stack. The moisture content of the straw increases to about 40%. Curing period is 3-4 weeks and ammonia retaining efficiency is >85%. The cost of urea treatment comes to about Rs 325/batch or Rs 75/tonne of material.

Feed block making machines have also been developed in which the crop residues are fortified with dried green grasses, berseem, salt etc and compacted into feed blocks. Such a machine developed at IARI New Delhi costing about Rs 14 Lakhs produces feed blocks at the rate of about 1 t/h. The cost of making feed block comes to about Rs 162/t.

National Dairy Development Board (NDDB) is using a feed block making machine of 1.5 t/h capacity for making feed blocks of balanced ration. Their experience of providing balanced ration, consisting of 30-50% roughage, bran, cakes, meal, grains, chunnies, kormas, food industry waste, molasses and minerals, to milch animals has shown that the cost of enriched straw pellets ex-works is about Rs5-6/kg packed in 30 kg HDPE bags. About 3000 milch animals are served with a 30 T/day plant and it has helped in increasing milk production from those animals by 1 L/day thus producing about 3000 litres/day of additional milk valued at Rs 60,000/day.

One metric tonne (Mt) of stored pellets of technically modified ration, during calamity, can serve 2 cows valued at Rs 50,000/-. Such feed block making machines for producing balanced ration for animals should be popularized.

4.1.2 Briquetting for animal feed

In addition to feed blocks, crop residues can be converted into low density briquettes (0.5-0.6 gm/cc), with or without fortification and can easily be handles, transported to long distances and stored properly for developing concept of **Fodder banks** in fodder deficit areas.

5. MECHANIZED HARVESTING, COLLECTION, BALING, HANDLING, TRANSPORT AND STORAGE OF CROP RESIDUES

5.1 Machinery for mechanised harvesting

Tractor operated Vertical Conveyor Reapers and self propelled combines are commercially available for harvesting of rice, wheat, Bengal gram, soybean, ragi etc. There are about 45 manufacturers of combines and their components in the country and more than 25000 combines are operating in the field. Annual production of combines is between 1500-1700 Nos.

These combines harvest the crop at different heights. For higher straw recovery it is advisable to harvest the crop close to ground level.

5.2 Machinery for mechanised baling

Field balers are nor being manufactured in the country but 4 manufacturers are supplying imported balers. These balers make rectangular bales of about 36x46x110 cm size weighing about 18-20 kg incase of wheat and 20-25 kg incase of rice. The bulk density of these bales ranges between 110-120 kg/m^3 incase of wheat and 125-130 kg/m^3 incase of rice. In developed countries tedder and gyro rakes for gathering the loose straw in a windrow and high density balers are available. They produce more compact bales having bulk density of more than 350 kg/m^3.

5.3 Field loaders

Tractor front mounted loaders are available with maximum lifting height of about 3.4 m and dump height of about 2.4 m. They can lift about 900-1000 kg of material and load in a trailer.

5.4 Specialized field trailers for transporting straw bales

Since the density of straw bales are low, specially designed trailers with low chassis heights are used for the transport of bales. Specialized wagons for road/rail/river or sea transport are needed. Specialized trailers used in advanced countries are of following sizes and capacities as shown in Table 7. For long distance transport the bale density should be more than 350 kg/m^3. A study conducted at GBPUAT Pantnagar has shown that the cost component for transport of bales in tractor trailer to 5 km distance consisted of 47% as collection and loading cost, 36% as hauling cost (to and fro) and 17% as

unloading cost. For long distance transport the component of hauling cost (to and fro) will be quite high. It is therefore advisable to first convert the bales into compact feed blocks or high density briquettes and then transport to long distances.

Table 7. General transport volumes and densities of trailers used in advanced countries for transport of straw bales

Size	Volume in m^3	Payload in kg	Minimum bulk densities for pay load in kg/m^3
12 m flat-bed truck/trailer	90	24,000	260
12 m rail truck	105	45,000	430
12 m offshore container	56	20,000	350

Two sets of high capacity equipment for harvesting, baling, handling and transport of crop residues should be imported, evaluated and adopted for Indian conditions. Such set of equipment should be got manufactured locally and popularize through Front Line Demonstrations.

5.5 Storage of bales

Bales should be stacked under a proper shed for long duration storage and used for different purposes, as and when required. Space requirement for storage of rectangular rice straw bales when stored in 7 tiers high is about 2-2.4 m^2/t, under covered conditions. If it is to be stored in open, it should be covered with nylon reinforced PVC sheets as is being used by FCI for grains.

The moisture content of straw should be less that 15% for safe storage and to prevent growth of moulds. If required Borax or any other suitable chemicals in desired quantity should be used to check growth of moulds. Precautions should also be taken for the control of rodents and fire hazards.

6. BRIQUETTING OF CROP RESIDUES FOR ENERGY

Briquetting is a technology for densification of crop residues to increase its bulk density, lower moisture contents, make briquettes of uniform size and shape for easy handling, transport and storage. It also helps in uniform burning when used as fuel. Briquettes have high specific density, about 1100-1200 kg/m^3 and bulk density about 600-800 kg/m^3 as compared to loose biomass which has bulk density in the range of 80-200 kg/m^3. Briquetting can be done with and without binder. Commercial high capacity machines do not use binder. At higher temperature (between 100-120 ^0c) the lignin present in the biomass gets fluidized and on applying pressure acts as its own binder. On cooling it solidifies and holds the briquettes intact. All crop and agro-processing residues and fruit and vegetable market wastes can be briquetted. If the lignin content in the biomass is low then it should be mixed with another biomass having high lignin content.

High density briquettes are used in boilers, gasifiers, furnaces and domestic cook stoves. The calorific value of crop/agro-processing residues varies between 3100-4500 kcal/kg. If used for power generation 1-1.25 kg of such residues can give about 1 kWh of electrical energy.

This technology should be popularized and briquetting plants should be established in production catchments.

Energetics of using crop residues and other biomass briquettes for energy purposes, both, thermal and power, shows that the total energy used in baling, transport of crop residues, drying, grinding and actual briquetting is about 8.35-10.96% of the electrical energy which could be produced from that crop residue.

An analysis of briquetting technology for converting surplus crop and agro-processing residues into briquettes shows that this technology is quite profitable. This can help in converting surplus biomass into fuel for domestic and industrial uses. One million tonnes of briquettes will replace about 0.3 Mt tonnes of LDO or diesel or can produce 0.8 to 1 million units of electrical energy. Even if 100-125 million tonnes of surplus biomass is used for power generation it can produce about 80-100 billion units of electrical energy valued at Rs 40,000-50,000 crores annually @ Rs 5/- per unit.

7. BIOMASS TO ENERGY CONVERSION ROUTES

Depending upon the characteristics of the biomass it could be used as energy for various applications, following different routes as shown in Table 8.

Table 8. Biomass to energy and energy carrier routes

Route	Process	Output		Application
		Main	Derived	
Thero-chemical	Combustion	Flue gas Thermic	Hot air, Hot water fluid, Steam	Drying, Heating, Power (Steam turbine and heat)
	Gasification	Producer gas	Methonol, Hydrogen	Heating, Power(IC engine, gas turbine),Chemical, Fuel cell
	Pyrolysis	Charcoal Bio-oil	Chemicals	Heating, Power (heating, IC engine, gas turbine)
Biological	Anaerobic digestion	Biogas	Hydrogen	Heat, Power(IC engine, gas turbine),Fuel cell
	Alcohol Fermentation	Ethanol		Power(IC engine)
Mechanical	Extraction	Oil	Ester	Power (IC Engine)

There are quite a few new developments in bio-chemical conversion processes of agro-residues. More R&D work is required to be done to refine the technology and put up pilot plants to demonstrate their techno-economic potential for future use and commercialization. Some of these developments are:

i) Solid state anaerobic conversion of residues into methane and compost has been demonstrated on bench scale (100 kg/day) at SPRERI Vallabh Vidyanagar. Based on this development, design of a system and selection of matching machinery for its operation and handling has been done to produce 450 to 2700 m^3 biogas per hour which would be sufficient to generate 1 to 6 MW power or 250 to 1500 m^3 of natural gas like fuel/hour which could be compressed and used as domestic fuel or running of tractors.

ii) Low cost and efficient sources of enzymes for saccarification of cellulose and pentosan contents of residues to produce fuel alcohol have been identified and further work on identifying new enzymes is going on.

iii) Technology for bacterial conversion of lingo-cellulogic materials to ethyl alcohol has also been developed and is being refined.

iv) Fermentation of producer gas to produce alcohol is being attempted at some places with encouraging results.

More concerted efforts are required to pursue these R&D works to develop appropriate technologies and pilot plants for production of biogas and alcohol.

In view of the greater demand of crop and agro-processing residues for animal feed only surplus amount of such residues should be used for energy purposed.

8. CHARACTERISATION OF BIOMASS

Different types of crop residues/byproducts/wastes and other biomass should be characterized for their possible future uses. These characteristics should include:

Physical : Shape, size, moisture content, angle of repose, equilibrium moisture content, density (true and bulk).

Chemical : Cellulose, hemi-cellulose, lignin, pentosans,

In case of fruits and vegetables—minerals, protein, vitamins, essential oils etc.

Thermal : Calorific value (higher and lower heating values), thermo gravimetric analysis.

Proximate analysis : Fixed carbon, volatile matter, ash

Elemental analysis : carbon, hydrogen, oxygen, nitrogen, other elements.

Applications of biomass based on their characteristics

i). Will help in selection of proper type of biomass for feed and fodder.

ii). Will help in selection of horticultural waste for different purposes, for extraction of chemicals, oil, fibre etc.

iii). From energy point of view biomass with low ash content and high CV and density are suitable for gasification and combustion e.g. all fuel wood species.

iv). High ash biomass with poor flow properties such as paddy husk are not suitable for gasification in downdraft gasifier with throat. However it is good fuel for throat- less and updraft gasifiers and furnaces.

v). Biomass with high silica e.g. rice husk and rice straw are good feedstock for crystalline and amorphous silica production.

vi). Rice husk is suitable feedstock for activated carbon production.

vii). Low density biomass (all straws and light stalks) with high cellulose content are suitable feedstock for bio-conversion process.

viii). High lignin biomass are good feedstock for binder less briquetting.

Detailed information on characterization of different types of biomass and agricultural wastes should be compiled and printed for proper utilization of different types of biomass.

9. ISSUES

Based on the deliberations in the Brain storming Session the following issues emerged.

1. Reliable information on the amount of different types of residues/ by-products / wastes from field and horticultural crops, fruit and vegetable Market waste, livestock and fisheries, which are being burnt/spoiled/wasted; region wise, season wise, are not available. In the absence of that, proper planning for their value addition and alternate uses for better utilization is not possible.

2. The above residues/ by-products /wastes are spread in different regions over a large area. They have to be collected quickly, specially the semi-perishable and perishable

ones, handled and transported to the places where they can be processed into value added products or utilized efficiently as such.

3. High capacity efficient package of equipment are required to collect crop residues, densify/ compact into high density bales or feed blocks, handle and transport to the place of storage/utilization. Due to their low bulk densities, even in densified form, their transport to long distances may not be economical.

4. Information on extent of crop residues which are needed to be incorporated in the soil in different regions to maintain soil organic carbon and fertility, without posing problems in seed bed preparation and sowing/planting of subsequent crop, is not available.

5. Burning of different types of agricultural residues/byproducts/wastes creates environmental and health hazard problems, besides loss of nitrogen from crop residues.

6. Transport of crop residues from surplus to deficit areas.

7. Equipment for mechanized harvest/collection, densification, handling and transport of crop and horticultural residues and other biomass are expensive and out of reach of small farmers.

8. Lack of awareness about the possible alternate uses of different types of agricultural wastes for their better economic returns.

9. Lack of awareness about the recent developments of utilization of crop and agro-processing residues, fruit and vegetable market wastes, effluents of agro-processing and dairy industries and other agricultural wastes for energy either through biogas production, low and high density briquettes for domestic use as fuel or use in the industry for thermal applications and power generation.

10. Development of low cost and efficient enzymes to produce ethyl alcohol from cellulosic material, which has good potential, has not received sufficient attention.

11. Information on desirable characteristics and classification of different types of agricultural byproducts and wastes for use as feedstock in industries for different economic uses like paper, fibre, medicinal products, cosmetics, paints and varnishes, natural dye, resins and gums etc and for conversion into energy and energy carriers is inadequate for planning and selection of feedstock and conversion processes.

12. Lack of awareness about the loss of nutrients due to improper composting of animal dung/excreta/urine/crop residues/fisheries wastes etc and their method of application in the field and incorporation in the soil, in solid or liquid form.

10. RECOMMENDATIONS

A. Policy

1. Proper, organizations, agencies, infrastructure and support system should be created at State and Central levels for collecting reliable data on different types of agricultural by-products/wastes and this data should also be published annually on the pattern of agricultural production data - district and state wise.

2. A realistic estimate of actual requirement of crop and agro-processing residues/ wastes for animal feed, mushroom growing and other uses should be made, district wise, to identify deficit/surplus areas for proper management of animal feed.

3. High capacity efficient machines for harvesting, baling, combining of straw, densification/compacting, handling and transport of crop residues should be introduced and popularized. For this purpose few pieces of equipment may be imported from advanced countries, evaluated, adopted and popularized .through **"Front Line Demonstrations"** in production catchments for harvesting and retrieval of crop residues for various purposes. Large users of biomass and entrepreneurs should be allowed to import such equipment for handling large quantities of loose and compacted biomass.

4. Procurement and custom operation of biomass management equipment should be promoted through financial incentives and training to the unemployed educated rural youth.

5. Surplus crop residues should be properly collected, baled, densified / compacted into feed blocks, fortified with specific blending of legumes and fodder trees to make them more palatable and digestible, in the production catchments and transported to fodder deficit areas to develop **Fodder Banks**. These fodder banks can provide safeguard for supply of fodder to the cattle during drought or lean periods.

6. A reliable estimate using remote sensing technique should be made to assess the quantity of crop residues being burnt annually in different regions and large scale burning of crop residues creating environmental pollution should be banned.

7. Breeders/agronomists should generate information on availability of straw at different heights of cut during harvesting. This will be useful to assess the quantity of straw/ crop residues which could be retrieved from field for different purposes. They should also generate/compile and publish data about the rations of main product to byproduct of different field and horticultural produce.

8. Surplus crop and agro-processing residues should be converted into low and high density briquettes for domestic and industrial uses for thermal application and generation of power.

9. Vegetable market waste should either be used for biogas and FYM production or converted into briquettes to be used as domestic and industrial fuel.

10. Biomass based pilot plants for decentralized power generation in the production catchments to meet the power needs of households and production agriculture and agro-industrial activities in the rural areas should be installed and operated by private entrepreneurs or cooperatives. In decentralized power generation mode 1 kg biomass briquettes can produce about 1 kWh of electrical energy. The experience gained from such pilot plants should be used to develop an extensive programme of utilization of surplus biomass for power generation.

11. Mechanised system for composting and its handling should be adopted. Standards for good quality compost should be formulated and popularized. Compost should be applied in October- November and should immediately be incorporated in the soil to avoid loss of nutrients.

12. Proper markets for perishables and semi-perishables be created with facilities of cooling the materials to avoid rotting due to high temperatures.

B. Research

1. ICAR should compile and publish information on technologies available for efficient utilization/ alternate value added uses of different types of agricultural wastes of field crops, horticultural crops, animal waste, fisheries and poultry waste with full details and cost analysis; identify gaps and need for refinement of technologies. This publication should widely be publicized and made available to user and entrepreneurs.

2. Suggest network mode of utilizing waste.

3. Classification of agricultural wastes and prioritization of their uses should be made.

4. All types of agricultural residues should be characterized and their performance for animal feed, incorporation in the soil, fermentation, extraction of essential oils, perfumes cosmetic products, minerals and other uses should be indicated.

5. Standards should be prepared for preparing good quality compost and vermin–compost on scientific lines.

6. Information on extent of crop residues required to be incorporated into the soil in different regions, districts to maintain soil health should be compiled and published for the benefit of farmers and extension workers.

C. Environmental Aspects

1. Large scale burning of crop residues/wastes causing environmental pollution should be banned. Forty to 80% of the nitrogen present in the crop residues is lost as ammonia when the crop residue is burnt.

2. FYM and biogas spent slurry after application should immediately be incorporated in the soil.

3. Construction of biogas plants should be kept away from the drinking wells.

4. Briquetting of crop, agro-processing residues and other biomass as domestic fuel in rural areas should be promoted along with high efficiency cook stoves using briquettes. Pilot plants for making briquettes should be installed in production catchments. Use of briquettes as domestic fuel will reduce the requirement of firewood and minimize felling of trees. This will improve the environment.

5. Effluents from agro-processing industries having high BOD and COD loads should first be treated anaerobically to reduce the BOD and COD loads to the required levels before releasing into drains and generate biogas which could be used for thermal application and power generation.

Appendix I: Estimated amount of crop residues produced in India during 2008-09 from different crops

In million tonnes

Sl. No	Crop	Main product	By-product	Ratio of main product to byproduct	Area in Mha*	Total production of main product Mt*	Estimatd production of byproduct Mt Mt	Present uses	Estimated Availability of surplus byproducts Mt
Cereals									
1.	Rice	Grain	Straw Husk and Rice bran	1:1.3	43.77	96.43	125.36 70.82	Animal feed, thatching, packaging Domestic and industrial fuel Oil, animal feed	15.0050.00-
2.	Wheat	Grain	Straw	1:1.5	28.15	78.40	117.60	Animal feed, paper industry	11.76
3.	Sorghum	Grain	Stalk	1:3	7.93	7.78	23.34	Animal feed	5.00
4.	Pearl millet	Grain	Stalk	1:4	9.50	9.79	39.16	Animal feed	5.00
5.	Maize	Grain	Stalk Spent cobs	1:41; 0.5	8.26	19.30	77.209.65	Animal feed Domestic fuel, FYM	7.705.00
6.	Other cereals	Grain	Straw	1:1.5	10.86	3.96	5.94	Domestic fuel, FYM	1.00
Pulses									
7.	Bengal gram	Grain	Straw	1:1.3	7.54	5.75	7.47	Animal feed, Hardy portion as FYM	2.00
8.	Pigeon pea	Grain	Stalk	1:4	3.78	3.08	12.32	Domestic fuel, thatching, leaves as animal feed	5.00
9.	Lentil	Grain	Straw	1:2	1.31	0.81	1.62	Animal feed	1.00
10.	Other pulses	Grain	Straw	1:1.5	11.23	5.48	8.22	Straw/haulm as animal feed	2.00
Oilseeds									
11.	Groundnut	Kernals	Strawl	1:1.11:0.50	6.29	9.18	10.304.59	Animal feedFuel	-3.00

			Shel						
12.	Rapeseed & mustard	Grain	Stalks	1:2	5.83	7.37	14.74	Domestic fuel, briquetting	7.00
13.	Soybean	Grain	Straw	1:1	8.88	10.97	10.97	Straw as animal feed Hardy stalks as FYM	3.00
14.	Sunflower flowers	Grain Empty	Stalks	1:21:1	1.91	1.46	2.881.46	Domestic fuelDomestic fuel	1.001.00
15.	Other oilseeds	Grain	Straw	1:1	3.70	2.24	2.24	Animal feed	-
16.	Cotton	Cotton	Stalk	3t/ha	9.43	25.81 million bales	28.39	Domestic fuel Some quantities are used for making particle board and some for briquetting	14.20
Commercial crops									
17.	Jute &	Fibre	Stalk	3t/ha	0.96 Mesta	11.18 millin bales	2.88	Domestic fuel	1.50
18.	Sugarcane	Sugarcane stalks	Trash and green tops Bagasse stalk	10% of stalk	5.04 20% of	340.56 **Total say 679**	34.06 68.11 **679.32**	Green tops as animal feed Trash/dry leaves are incorporated in the soil. Bagasse- as animal feed, briquettes/fuel **say 233**	23.84 68.11 **233.11**

*Mha. Million hectares; Mt. Million tonnes (metric tons)

Source: Data on area and production of main products taken from “Agricultural Statistics at a Glance 2009”. Published by the Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Govt of India. Website (http://www.dacnet.nic.in/eandds)

Appendix II: Estimated amount of horticultural crop residues produced in India during 2008-09 from different crops

Sl. No.	Crop	Main product	By-product	Area in 000 ha	Total production of main	Estimated production product in Mt*	Present uses of byproducts of byproduct in Mt	Estimated Availability of surplus by-products in Mt
A)	**Fruits**							
1.	Apple	Fruit	Spoiled/rotten fruits Pruning material	271	1,985	In fruits there are lot of variations in main product to by-product ratio. On an average it may be assumed as 1:1Besides aboveabout 20% of fruits are spoiled in harvesting, handling and transport	Only about 50% of the by-products and spoiled fruits are collected and are used as manure	Only about 50% of the by-products and spoiled fruits are collected.
2.	Banana	Fruit	Banana peal, banana stems	708	27,119			
3.	Citrus	Fruit	Spoiled fruit, peal	926	8,528			
4.	Grapes	Fruit	Spoiled fruit, pruning material	69	1,764			
5.	Guava	Fruit	Spoiled fruit, pruning material	207	2,330			
6.	Litchi	Fruit	Peal, seed	72	433			
7	Mango	Fruit	Peal, mango stone	2,309	12,831			
8	Papaya	Fruit	Peal	98	3,641			
9	Pine apple	Fruit	Peal, used plants	84	1,354			
10	Pomegranate	Fruit	Empty fruits	109	856			
11	Sapota	Fruit	Peal	156	1,309			
12	Others	Fruit	Peal	1,097	7,303			
			Total of (A)	**6,106**	**69.453**	**83.344**		**41.672**

B) Plantation Crops								
13	Coconut	Kernels	Dry leaves Coconut shells Coconut fiber Coconut pith	1940	10.894	About 3t/ha 5.820	Dry leaves as fuel Used as fuel Used as coir, rope making, foot mats Manure	About 70% is recovered 4.074
14	Cashew nut	Kernels	Shell, apple and husk	893	0.695	0.695	Apple as fenny-alcohol, sulphur oil, other by-products as fuel	0.695
15	Areca nut	Hard kernels	Shell	387	0.481	0.481	As fuel	0.695
16	Cocoa	Beans	Shell	34	0.012	0.012	As fuel	0.012
Total of (B)				**3254**	**12.082**	**7.008**		**5.476**
C) Vegetables								
1	Brinjal	Brinjal	Stalk	602	10.420	In vegetables also there are lot of variations in main product to by-product ratio . On an average it may be assumed as 1:1 Besides above about 30% of fruits are spoiled in harvesting, handling and transport	Only about 50% of the by-products and spoiled vegetables are collected and are used as manure	Only about 50% of the by-products and spoiled vegetables are collected
2	Cabbage lower	Cabbage lower	Old and loose leaves	308	6.805			
3	Caulif	Caulif	Old and loose leaves	358	6.566			
4	Okra	Okra	Stalk	436	4.524			
5	Onion	Bulb	Stalk	836	13.972			
6	Peas	Grain	Grain less pods	349	2.914			
7	Potato	Tuber	Haulm	824	36.284			
8	Sweet Potato	Tuber	Haulm	1.121	124			
9	Tapioca	Tuber/ root	Stalk	280	9.623			
10	Tomato	Tuber	Haulm	606	11.328			
11	Others	Leaves/ flower	Stalk	2,299	29.514			
Total of (C)				**8,024**	**133.071**	**172.992say 173**		**86.496say 86.50**

D) Other crops/items							
1	Mush room	Mush room	Spoiled and left over		0.037	Estimated production of byproducts is 5,000 t	As manure	-
2	Honey	Honey	Honey comb		0.065		Wax preparation	-
3	Spices	Spices	Plant material	2629	4.145		As manure	.001
Total of (D)				**2629**	**4.247**	**0.005**		**0.001**
Grand Total of (A+B+C+D)				**20,710**	**220.484 say220.50**	**268.344 tonnes say268million**		**133.645 say 134 million tonnes**

*Mt - Million tonnes

Source: Agricultural Statistics at a Glance 2009. Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Ministry of Agriculture, Govt of India. Website (http://www.dacnet.nic.in/eandds)

Appendix III Biomass available as waste from road sides, waste lands, forests and social forestry

Source of Biomass	Approx. availability of Biomass waste in million tonnes
Biomass produced on road side	10.71
Biomass produced on waste lands	27.12
Biomass produced from forest	157.18
Biomass produced as agro-forestry waste	9.06
Total	**204.07 say 204**

Source: Pathak, P.S., Khan, T.A and Sharma Purushottam (2004) Biomass Production, its Utilisation and surplus for Energy Generation in India. In:Biomass Management for Energy purposes—Issues and Strategies: Ed: B.S.Pathak and N.S.L.Srivastava. SPRERI Vallabh Vidyanagar.

Appendix IVa: Average dung/excreta produced per animal per year (DM Basis)

Species	Range (t/year)	Average (t/year)
Cattle	0.4-1.8	1.10
Buffalo	0.8-1.9	1.35
Camel	0.7-0.9	0.80
Horses and donkey	0.4-0.6	0.50
Pigs	0.2-0.3	0.25
Sheep and goats	0.1-0.2	0.15
Poultry (100 birds)	0.14	0.14

Source : Jain, M.C and Kumar, Shushil (1995). Recycling of animal waste in agriculture. In: Recycling of crop, animal and industrial wastes in agriculture by H.L.S. Tandon. Published by Fertiliser Development and Consultation Organisation, New Delhi.

Appendix IVb: Estimated annual availability of dung/excreta produced by animals and poultry (DM Basis) on the basis of population of livestock and poultry in 2003

Species	Population in	Average Annual 2003 in millions production of dung/ excreta on DM basisin	Total annual production of dung/ excreta on DM basis in tonnes million tonnes
A) Animals			
Cattle	185.181	1.1	203.699
Buffaloes	97.922	1.35	132.195
Horses and Ponies	0.751	0.50	0.375
Mules	0.176	0.50	0.088
Camels	0.632	0.80	0.505
Donkeys	0.651	0.50	0.325
Sheep	61.469	0.15	9.220
Goats	124.358	0.15	18.634
Pigs	13.519	0.25	3.380
Yaks	0.065	1.1	0.071
Mithuns	0.278	1.1	0.306
Total	**485.002**		**368.798**
B) Poultry **Poultry**	**489.012**	**0.0014**	**0.685**
Grand Total of A+B	**974.014**		**369.474** **say 369.50**

Source : Population of animals taken from "Basic Animal Husbandry Statistics, 2008, Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India.

Appendix V : NPK Content in animal waste

Material	Nutrient content (%)		
	Nitrogen	Phosphorus	Potash
Meat meal	10.5	2.5	0.5
Blood meal	10-12	1-2	1.0
Horn and hoof meal	10-15	1.0	-
Raw bone meal	3-4	20-25	-
Steamed bone meal	2-5	26-28	-
Fish meal	4-10	3-9	1.8
Leather waste	7.0	0.1	0.2
Hair and wool waste	12.3	0.1	0.3

Source : Jain, M.C. and Kumar, Shushil (1995). Recycling of animal waste in agriculture. In: Recycling of crop, animal and industrial wastes in agriculture by H.L.S. Tandon. Published by Fertiliser Development and Consultation Organisation, New Delhi.

Appendix VI : Harvest and Post-harvest losses in Inland Fisheries

Resource	Overall losses (%)	Reason for the losses
A)	**At Producer Level**	
Fresh of water acquaculture	2.40	Physical due to faulty handling practices and discarding uneconomical sized, spoiled or bruised species.
Brackish water acquaculture	1.86	Physical due to faulty handling practices and discarding of uneconomical sized, spoiled or bruised species.
Reservoir fisheries	6.52-8.89	Spoiled due to inordinate delay in harvesting time & insufficient icing and physical losses or bruises due to faulty handling practices, fishing gear etc.
Lake fisheries	3.69-4.48	Spoilage due to adverse condition, delay in harvesting time & insufficient icing and physical losses or bruises due to faulty handling practices, fishing gear etc.
Riverine fisheries	8.56-13.94	Adverse weather condition (summer, muddy water during post monsoon season), delay in harvesting time & insufficient icing and physical losses or bruises etc.
Eastuarine fisheries	6.32	Spoilage due to adverse condition, delay in harvesting time and insufficient icing.
B)	**At Market Level**	
Channel	**Overall loss (%)**	**Reason for the losses**
Packaging	0.29	Due to faulty handling practices at loading/un-loading, packaging, spoilage due to delay in transporting and storage.
Pre-processing	0.19-1.57	Spoilage due to delay in transport, insufficient icing and discarding of little meat portion.
Processing	0.15-0.54	Spoilage due to delay in transport, insufficient icing at raw material receiving stage.
Whole Sale Markets	Up to 10.98	Due to poor infrastructural facilities and huge volume of arrivals from far away landing centres. Hot weather during pre-monsoon and lack of demand during monsoon season also play a major role.
Retail markets	2.96	Losses due to improper packaging, insufficient icing, delay in transport.
Vendors	4.10-5.52	Discarding/spoilage due to lack of demand.

C) At Consumer Level		
Channel	**Overall loss (%)**	**Reason for the losses**
Households (Urban)	4.41-4.52	Due to discarding of spoiled fish or bruising of some part during cleaning.
Households (Rural)	3.94	Due to discarding of spoiled/bruised fish.

Source: Final Report of NATP Mission Mode project on Assessment of Harvest and Post Harvest Losses in Inland Fisheries (2005). Report prepared by Indian Statistics Research Institute New Delhi and Central Institute of Fisheries Technology Cochin and submitted to NATP/ ICAR.

Appendix VII: Harvest and Post-harvest losses in Marine Fisheries

Sector	**Overall losses (%)**	**Reason for the losses**
At Producer Level		
I) Within Craft/gear		
Traditional	4.13	Due to retention of catch in the craft and gear, handling losses during unloading, use of fish as bait in hook and line fishing, attack by large species, discard of juveniles in heavy quantities specially during pelagic trawling and spoilage due to improper icing.
Motorised	3.61	The losses observed in this sector were also due to similar causes as in the case traditional fishing. Rough season during monsoon also resulted in the physical loss of harvest due to inability to bring the catch to the shore.
Mechanised and medium)	14.48	Multi-day fishing (3-5 days) reported maximum loss (Small due to capture of juveniles and their discard in the sea even before landing. Low market price of the varieties caught and the limitation in the fish hold capacity on board were the main reasons for discard of such fish
Large trawlers	21.41	Multi-day fishing (15-20 days) reported maximum loss due to capture of juveniles and their discard in the sea even before landing. Low market price of the varieties caught and the limitation in the fish hold capacity on board were the main reasons for discard of such fish
At Market Level		
Channel	**Overall losses (%)**	**Reason for the losses**
Pre-processing (fresh fish)	0.26	Losses occurred due to faulty handling and discard of small size fish. Loss also occurred in shrimps in washing, grading and packing.
Pre-processing	0.14	Pre-processing centres handled shrimps from different places outside the state. In such cases black spot and discolouration were frequently observed. Improper icing and exposure to ambient temperature while in transportation also spoiled the fish.

Processing (Fresh)	0.15	Losses occurred due to discolouration, black spot, broken tanticles and wings. During glazing also loss occurred.
Processing (Frozen)	0.03	Due to poor infrastructural facilities and huge volume of arrivals from far away landing centres. Hot weather during pre-monsoon and lack of demand during monsoon season also play a major role.
Wholesale (Fresh)	2.17	Major reason for losses in whole sale market are market handling losses and losses due to spoilage. Improper icing and exposure to ambient temperatures are the main causes for spoilage..
Wholesale market (dry)	8.28	The major reasons for losses are same as that of fresh fish market. However, spoilage of fish due to high humidity and insect infestation are also found.
Major retail (Fresh)	0.16	Major reason for losses in whole sale market are market handling losses and losses due to spoilage
Major retail (dry)	2.40	Major reason for losses in whole sale market are market handling losses and losses due to spoilage
Minor retail (Fresh)	1.89	Major reason for losses in whole sale market are market handling losses and losses due to spoilage
Minor retail (dry)	6.43	Major reason for losses in whole sale market are market handling losses and losses due to spoilage
Roadside market(Fresh)	2.35	Major reason for losses in whole sale market are handling losses and losses due to spoilage
Roadside (dry)	5.86	Major reason for losses in whole sale market are market handling losses and losses due to spoilage
*Drying unit at Alappuzha	58.07	Non availability of a suitable high capacity dryer. Insect infestation and attack by birds and animals also resulted into high losses.
*Drying unit at Calicut	19.36	Non availability of a suitable high capacity dryer. Insect infestation and attack by birds and animals also resulted into high losses.
Vendor	9.73	Discarding/spoilage due to lack of demand.
At Consumer Level		
Sector	**Overall losses (%)**	**Reason for the losses**
Households (Urban)	1.93	Due to discarding of spoiled fish or bruising of some part during cleaning.
Households (Rural)	4.95	Due to discarding of spoiled/bruised fish and non availability of refrigerators for short time storage…

Source: Final Report of NATP Mission Mode project on Assessment of Harvest and Post Harvest Losses in Marine Fisheries (2005). Report prepared by Indian Statistics Research Institute New Delhi and Central Institute of Fisheries Technology Cochin and submitted to NATP/ICAR.

Appendix VIII: Waste generation in industrial fish processing in India

Products	Waste generated (%)
Shrimp products (PD, PUD, HL, etc.)	50
Fish Fillets	70
Fish steaks	30
Whole and gutted fish	10
Cuttlefish rings	50
Cuttlefish whole	30
Cuttlefish fillets	50
Squid whole cleaned	20
Squid tubes	50
Squid rings	55

Ref.: Anon (2005) *Assessment of Harvest and Post Harvest Losses in Marine Fisheries*. CIFT Publication, Central Institute of Fisheries Technology Cochin.122p

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