Harvesting and handling of miscanthus

Danish experiences

Erik Fløjgaard Kristensen
Danish Institute of Agricultural Sciences
Research Centre Bygholm

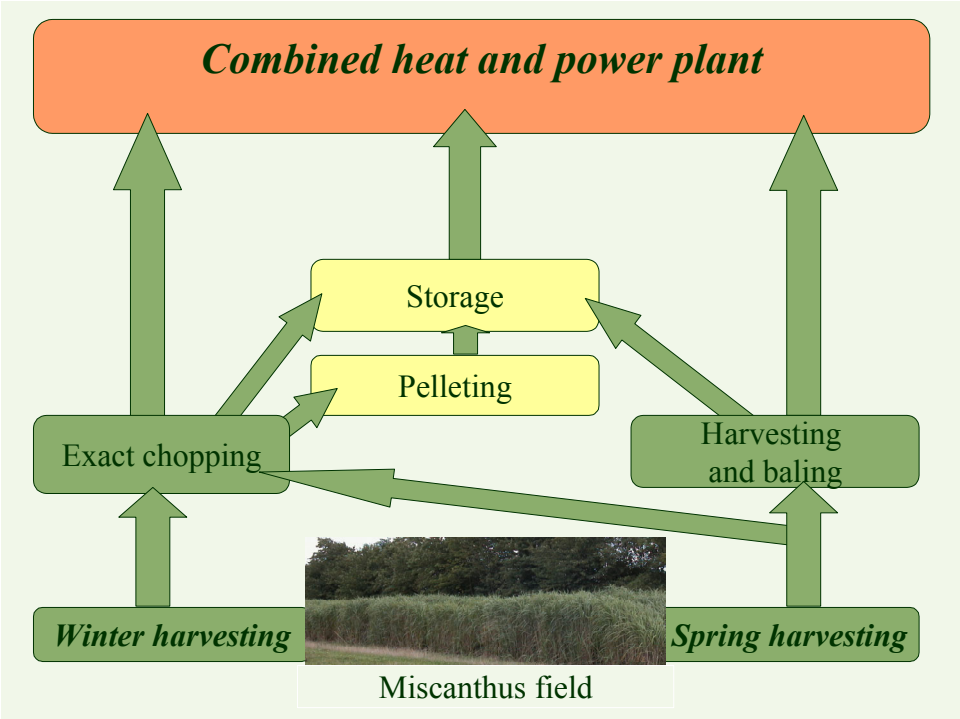
An increased use of biomass plays a major role in the Danish energy policy described by the action plan "*Energy 21*". So far, the effort has been concentrated on exploitation of the available biomass residues, mainly straw and wood, before initiating a major exploitation of energy crops. However, the contribution from energy crops is expected to increase steeply from 2012 to 2030.

Energy crops can be divided into annual and perennial crops. Among the annual crops in Denmark, the highest interest has been in the growing of whole crop grain and rape seed. The advantages in the growing of these crops are: well-known technology, the farmers already have the requisite machines, and that the production can be changed within one year if the marketing possibilities change in favour of growing another type of crop.

However, the growing of perennial crops might offer essential environmental advantages. Miscanthus is a crop that might be of interest in Denmark. It has a high yield potential and a low fertiliser demand. Besides, established miscanthus plants will have none or only a very low demand for pesticides, and the leaching of nitrate to the ground water from miscanthus fields will be very low.

For future application of miscanthus within the energy sector, there will be a demand for rational techniques and systems for harvesting, handling, transport and final use. The field harvesting techniques must be in harmony with the techniques used subsequently by the end users. Purchasers of miscanthus for combustion purposes will typically be heating plants or combined heat and power plants (CHP plants). Biomass combusting plants are often designed for combustion of big baled dry straw or wood chips. Since miscanthus is a very sturdy and stiff-strawed type of crop, the demands on the applied harvesting material are very high. Some machine technical solutions for the harvesting are described in the following.

Outline of different ways to perform harvesting and handling of miscanthus



Time for harvesting

The harvesting may take place in the period from October/November when the crop has passed its ripening stage and until the following spring when the plants again begin to sprout. The combustion quality will be highly dependent of the time of harvesting. The crop's moisture content will decrease from 60-70% in the autumn to less than 20% in April. During the winter, the plants will shed their leaves, and mineral leaching from the straw due to rain will take place. The consequent reduction in the content of ashes, potassium and chloride will make up a technical advantage in connection with combustion. The best fuel quality will thus be obtained from spring-harvested miscanthus. The soil type will moreover have significance for the ash and mineral contents of the crop, which will be lowest for miscanthus grown on coarse sandy soils.

Fuel quality of Miscanthus 'Giganteus' at different harvesting and growing conditions

Harvest time	April/May (delayed harvest)		December
Soil type	Sand	Clay	Sand
Moisture content, %	15.0	9.6	56.0
Ash, %	1.0	2.7	3.1
Chloride, g/kg (Cl)	0.2	8.0	3.3
Potassium, g/kg (K)	1.65	3.2	10.1

In spite of the low fuel quality, winter harvest may sometimes be an advantage, because of the higher yield of biomass dry matter compared to spring harvest (delayed harvest). Moreover, winter harvest will often permit direct delivery of the crop to the heating plant, because the harvesting will take place during the heating season. Reductions in the storage costs can be obtained on direct delivery.

Harvest machines
The following machines and machinery chains can be used for harvesting of miscanthus:

- Exact chopper with row independent maize header
- Mower and subsequent collection with exact chopper equipped with pick-up
- Mower and subsequent collection with big baler
- Big baler mounted with chopper
- Exact chopper and big baler in one unit

All the above-mentioned techniques are applicable for spring harvesting, but the big baling system is unfit for winter harvesting, due to the high moisture content of the crop in the winter.

For the mowing of miscanthus conventional disc mowers equipped with crimpers will be applicable. The capacity will be lower than for mowing of grass and energy grain. The maximum forward speed was about 9 km/h for both winter and summer harvesting. The crimping must be performed in an effective way, and the resulting swath should be even and uniform. Otherwise, there will be a high occurrence of machine stops during the subsequent collection of the crop by means of pick-up.

Both self-propelled and trailed exact choppers can be used for miscanthus harvesting. For direct harvesting, row-independent maize headers will be suitable. In general, self-propelled machines have the highest capacities. The degree of fineness will influence the capacity significantly. Therefore, the chopping degree should not be any finer than required by the end user.

Harvesting of miscanthus by means of exact chopper

Machine	Kverneland Ten-X with pick-up[1)]	Claas Jaguar 690 with pick-up[2)]	Kverneland Ten-X with pick-up[1)]		Claas Jaguar 820 with maize cutter bar[2)]
Harvest time	Spring (delayed harvest)		Winter (December)		
Moisture content, %	15.0	12.2	51.2	50.7	56.0
Yield, t/ha	10.5	14.9	31.2	23.3	16.3
Cutting length, mm	14	12	14	34	4
Net capacity, t/h (t DM/h)	9.7 (8.2)	12.1 (10.6)	20.2 (9.9)	29.8 (14.7)	21.9 (9.6)

[1)] Trailed chopper. [2)] Self-propelled exact chopper.

One advantage of harvesting with exact choppers is that the material will be applicable for direct use in automatic stokers and chip combusting plants. A rational method of harvesting and delivery will be harvesting by means of exact chopper with container platform and transport of the filled containers to the heating plant by means of lorry. The density of chopped miscanthus is very low, i.e. about 80 kg of dry matter/m^3. This will be a disadvantage in a handling situation, especially in the case of long distance transport.

Properly mowed miscanthus can usually be collected and baled without problems by means of Hesston 4800/4900 big balers. The baling capacity will be lower for miscanthus than for straw, because the structure of the material (long and stiff) may cause stops of the pick-up and the feeding mechanism. Net capacities of about 16 tonnes of fresh weight per hour have been observed. In order to obtain proper handling of big bales at heating plants with automatic crane systems, a high bale

quality in terms of stability and shape will be needed. To fulfil these requirements, an optimum adjustment of the balers will be needed. As will appear from the table below, miscanthus bales will weigh about 600 kg, which is the same as or slightly more than straw bales. The bale density will be from 140 to 170 kg/m^3.

Hesston 4800 big balers mounted with choppers can be used for simultaneous harvesting and baling. Compared to conventional big baling, the chopping will result in slightly reduced capacity and increased power requirement. This harvesting method will provide very regularly shaped bales. For simultaneous chopping and baling, the bale weight will in general be a little higher than for conventional big baling. However, the fact that the tractor moves about in the not yet harvested crop during the harvesting might be rather impractical.

Big baling of miscanthus (harvest in spring)

Machine	Hesston 4800	New Holland 499(	Hesston 4800 with Ferri f200 choppe
Moisture content, %	22.3	14.1	13.3
Yield, t/ha	13.2	10.7	10.0
Bale weight, kg	630	560	590
Power requirement[1)], kW	20.6	–	53.7
Net capacity, t/h (t DM/h)	16.8 (13.1)	15.9 (13.7)	14.7 (12.7)

1) PTO power requirement. Additional power will be needed to pull the machine.

The advantage of the big baling methods will be that the subsequent handling and transportation can be performed in a rational manner. The system for delivery of big baled straw to heating plants and CHP stations is well known and well established.

Storage

In the case of spring harvesting, miscanthus may be handled and stored like dry straw, whereas for winter harvesting, the storability of the crop will be poor. The crop may be dried, but due to its high moisture content, the energy demand will be high. It was found that an energy consumption of 4 MJ per kg of dry matter was needed to dry miscanthus harvested in November/December with moisture content of 59%.

Different methods for storage of moist, winter harvested miscanthus in outdoor piles have been examined. The simplest method was found to be outdoor storage in piles covered with plastic foil. The microbiological activity in the moist material will cause temperature increases, decomposition of the crop, fungi spores, dry matter losses and moisture content increases. If the crop is stored in outdoor piles with channels for natural ventilation, it will be dried to some extent. But here too, the microbiological activity will cause temperature increases and dry matter losses, etc.

Loss and changes in moisture content at different methods for storage in outdoor pile

Method	Storage period	At start of trial		Reduction of moisture content. Pct. points	Dry matter loss %
		Weight kg	Moisture content %		
Airtight storage	6 months (December until June the following year)	13910	53	0	1
		2580	54	-2	5
Covered storage		12020	53	-5	17
Natural ventilation		12500	51	11	7
		17700	56	5	18

For both methods, dry matter losses of up to 18% were seen in the case of storage over six months (see the diagram below). From a working environmental point of view, the subsequent handling may become problematic, because of the high content of fungi spores in the crop. If the pile is laid out on, and covered with plastic foil, airtight storage can be obtained. Airtight storage of the crop can be a way to prevent dry matter losses and decomposition of the crop, but no drying effect will be obtained.

Pelleting

Pelleting plants for sawdust can also be used for pelleting of miscanthus that has been harvested with exact chopper. Addition of glue or other adhesives will not be necessary. Pelleting may offer many advantages in connection with handling and transport, and the miscanthus pellets will have a variety of applications in connection with combustion.

References

The Danish Energy Agency, 1996. Energy 21, the Danish Government's Action Plan. The Ministry of Environment and Energy.

Fenger, L.D., 2001. Fyringsforsøg med alternative biobrændsler (Heating tests with alternative bio-fuels) (in Danish). Masnedø Kraftvarmeværk. Energi E2.

Jørgensen, U. & Kristensen, E.F., 1996. European Energy Crops Overview. Country Report for Denmark.

Jørgensen, U., 2000. Har energiafgrøder en fremtid i Danmark? (Do energy crops have a future in Denmark?) DIAS Report No. 29. Markbrug. Danish Institute of Agricultural Sciences.

Jørgensen, U. & Kjeldsen, J.B., 1992. Grøn Viden, Landbrug, No. 110. Danish Institute of Plant and Soil Science.

Kristensen, E.F., 2001.Teknik til høst af miscanthus (Technique for harvesting of miscanthus) (In Danish with English summary). DIAS Report No. 55. Markbrug. Danish Institute of Agricultural Sciences.

Kristensen, E.F., 1998. Høst af elefantgræs. (Harvesting of miscanthus) (in Danish) Grøn Viden. Markbrug, No. 202. Danish Institute of Agricultural Sciences.