A PLAN FOR COMMERCIALISING SORGHUM AS A SUGAR CROP IN NORTHLAND

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ABSTRACT

Sweet sorghum was investigated as a potential sugar crop in Northland by a series of small-scale field and laboratory trials. This work is reviewed and the features of a pilot scale refined-syrup industry are mooted. Assuming the syrup would sell at a similar price to cane sucrose on a dry-saccharides basis, the culture and processing of sorghum appears technically and economically feasible although pilot production would be needed to confirm such indications.

Additional Key Words: *Sorghum bicolor, sweet sorghum, syrup*

INTRODUCTION

The potential of sorghum as an international sugar crop has been recognised for over a century. Even New Zealand had a fledgling sorghum-sugar industry during the 1880's (London, 1974). However, the only permanent sorghum-sugar manufacture has been the table syrup industry of the south and east USA (Coleman, 1970). Recently the crop has attracted attention as a source of ethanol and our research programme was initiated to investigate such an 'energy farming' concept (Piggot and Farrell, 1980). Much of our work has involved agronomic studies (Piggot and Farrell, 1984) but abstract schemes adapting sorghum-energy farming into Northland's agricultural and agro-industrial systems have been published (Piggot, 1982a, 1982b, 1983). The assumption that "the development of an indigenous, but internationally competitive, sugar industry may be a prerequisite to future ethanol production from sweet sorghum in New Zealand" (Piggot, 1982b) has focussed our research programme into an appraisal of ways of commercialising sorghum as an indigenous sugar crop. The term 'sugar' is used here generally to denote sweet saccharides not solely dry (cane) sucrose. The purpose of this paper is to present a 'blueprint' of the embryonic development of a sugar industry based on sorghum; i.e. the production of sugar from less than 1,000 hectares of crop. The development of a larger mature industry is assumed to occur by evolution. Its growth would be driven by competitive pricing relative to alternative carbohydrate sweeteners.

The choice of refined syrup as a final product was favoured over ethanol on economic grounds and over dry sucrose on technical issues. Syrup does not have a clearly defined market in New Zealand but it is possible that small scale sorghum syrup production would slot into a specialist end use related to its seasonality of production, or be sold as a table syrup. From the viewpoint of the local economy the benefits of such a sugar industry are a diversification of land use and provision of sugar-extracted crop residues for traditional pastoral agriculture (Piggot, 1983). Such a scheme should appeal to both farmers and the processed food industry. The process would consist of crop production, harvest by modified forage harvester, milling of stalk segments, consumption of residues by livestock, cartage of raw juice to factory, refining and sale as concentrated syrup.

CROP CULTURE AND YIELD

The sites where best yields have been obtained (Piggot and Farrell, 1984) were sheltered and had drained (naturally or artificially) alluvial loamy or clay soils. Minimum tillage techniques can be used to establish sorghum. The land would be grazed in mid October, sprayed with herbicide (paraquat or glyphosate) in late October and power cultivated prior to sowing in mid November. Seed would be drilled at 10-15 kg/ha in 30 cm rows and phosphatic fertiliser applied with the seed. Provided the land had previously been in pasture, no nitrogen or potassic fertiliser, or insecticide would be required. A pre-emergence selective herbicide (atrazine) should be applied. Minimal seasonal crop surveillance for weed and pest control would be necessary. The varieties chosen would depend on end use (e.g. syrup vs sugar types — Coleman, 1970) and maturity ranking relative to harvest timing (see below). Detailed yield data with such crop management is provided by Piggot and Farrell (1984); i.e. a good crop yielding 20 t DM/ha providing 4 t dry saccharides.

HARVESTING

Timing

Stalk sugar content reaches a maximum prior to maturity dictating a narrow harvest period. For quality end uses, juice extraction and refining must be prompt as neither the cut stalks or raw juice store well for long periods at ambient temperatures (Coleman, 1970; Daeschel *et al.*, 1981; Hurst, 1982). In contrast, economic efficiency of processing operations dictates a lengthy harvest season. Agronomic treatments can bridge this gap. It has been shown (Piggot and Farrell, 1984) that cutting treatment and cultivar maturity influence the ultimate harvest timing. Further trial work to optimise these factors was conducted at the Otakanini trial site in the 1984/85 summer. Trial techniques were as previously described (Piggot and Farrell, 1984) and the results (Table 1) match our previous work and clearly demonstrate that, with judicious land allocation to separate varieties allied with appropriate February cutting, the harvest season in Northland could stretch from mid February to late June (120 days) assuming minimal frost damage.

TABLE 1: Approximate date of 'milky' stage (Freeman *et al.*, 1973) from sowing on 19 November 1984 of six cultivars for uncut crop or crop cut on 7 February 1985.

Cultivar	Uncut crop	February cut
Roma	25 February	25 May
Ramada	1 March	25 May
M 81 E	20 March	mid June
Keller	1 April	mid-June
Wray	25 April	unknown
FS 26 (forage type)	15 March	1 June

Method

Whole crop harvesting by a modified forage harvester followed by multiple milling with water imbibition appears the preferred method for harvesting and sugar extraction. Such a method is modelled on the community-sized syrup plant described by Wright *et al.* (1977) which would service 100 hectares over a 120 day harvest period. Apart from the centralised mill other equipment is widely available in Northland. Portable mills might appear attractive (e.g. Piggot, 1982a) but have problems of low extraction efficiency and low crop throughput (Nuese and Hunt, 1983) and such sorghum harvesters have yet to be commercially proven. Residue from this extraction operation is functionally separated into a seed-heads-and-leaf fraction and a fibrous-pulp or bagasse fraction, essentially high and low value fractions viewed from the animal feeding viewpoint (Piggot, 1983). Profitable disposal of the bagasse may present problems although it has numerous potential uses (Ferraris and Stewart, 1979; Creelman *et al.*, 1982).

PROCESSING

Small scale methods of processing raw sorghum juice to table syrup have been well documented (Freeman *et al*, 1973; Hurst, 1982). Such methods, accepting their associated scale and product marketing limitations, are as applicable to Northland as to the USA. Our studies investigated a processing concept which integrated local expertise about sugar syrups with the processing equipment in the dairy industry (Piggot, 1982b). The work consisted of fermentation studies (Piggot, 1982a), laboratory experiments with raw sorghum juice (R.D. Carson, Kaipara Cooperative Dairy Company, *pers. comm.*), chemical and sugar spectra analyses of raw juice (Piggot and Farrell, 1984), microbial stability of raw juice (G.R. Bailey, New Zealand Starch Products, *pers. comm.*), and methods of refining and stabilising raw juice (unpubl. data). The raw juice for experimentation was derived from a small three-roller field mill with a low extraction efficiency. Whether raw juice composition would differ from an efficient factory-scale mill was not determined. The cloudy, raw juice was centrifuged at 8000 g to remove particulate suspended matter. The clear supernatant was heat treated to 95-100 °C for one minute to coagulate the heat-labile proteins. Whereas Hurst (1982) applied heat treatment after addition of calcium salts to the juice, we applied heat at the normal pH of the sorghum juice thus maintaining a slight acidity in the product. Insoluble material was allowed to settle overnight at 2-4 °C whereupon a heavy white sediment was obtained. Final clarification was achieved by filtering the chilled juice through a 0.45 μ Millipore membrane filter. The sparkling clear filtrate was concentrated under vacuum at 45-50 °C in a Buchi rotary evaporator to 70° Brix. The resultant amber coloured concentrate had a stable shelf life in ambient conditions of at least six months and could be diluted to yield sparkling clear juice.

TABLE 2: Parameters of processing.

Processing factors	
Saccharide recovery	80%
% soluble solids in syrup	70%
Crop throughput	6 t/hour
Total crop harvested (120 day season)	6400 t
Seedhead + leaf	600 t DM
Stalk	700 t DM
Total dry saccharide yield	350 t
On farm factors	
Average crop yield at maturity	80 t/ha
(Cut and uncut crop average)	17 t DM/ha
Varieties sown	3
Proportion cut in February	
(of early maturing varieties)	40%

ECONOMICS

Pilot scale sorghum syrup production has not been conducted so any economic assessment can only be speculation. A syrup price from a factory situated within 100 km of Auckland of $NZ800/t (dry saccharides basis) should provide a competitive product. Given the processing and yield parameters of Table 2 the costs of processing raw stalk (i.e. transport, milling, clarification, evaporation, storage) including a return on capital investment of 25%, are 'guesstimated' to approach $400/t. This leaves $400/t for the farmer or $1,600/ha for a good crop. After deducting costs of culture and harvesting this provides a return ($800/ha) similar to dairying, which is the primary land use of suitable cropping land at present. The farmer should also profit from feeding livestock the seedhead and leaf residues resulting from crop processing, plus gain income from the use of sorghum land out of the cropping season in a grazing system.

CONCLUSION

Information is available to enable the setting up of a pilot sorghum-sugar production system in Northland. The pilot plant would require both agronomic and engineering expertise allied with sufficient capital investment and access to 50-100 ha of suitable cropping land. Elements of the processing and marketing or a sorghum syrup are the most prominent problems requiring further resolution.

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