

# COCOA GROWERS' BULLETIN

Contents

Number 48



**Cadbury Limited**
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## EDITORIAL

This Issue of the Cocoa Growers' Bulletin focuses on flavour with a variety of articles on different aspects of the subject. There are many misunderstandings about cocoa flavours and it is hoped that by this means some of them can be dispelled.

A chocolate manufacturer needs cocoa beans which can be processed into chocolate with a good flavour, which his consumer will enjoy. This is the most important property of the cocoa bean but it is a property which has been poorly defined and has proved hard to assess objectively. The only possible way to assess the flavour is by manufacture of chocolate followed by it's submission to a taste panel.

Until very recently there has been no broadly-based agreement on the methodology of making such chocolate samples on a laboratory scale or indeed of the conduct of a taste panel or the terminology to be used. This has made flavour research by biochemists or plant breeders extremely difficult and in some instances has actually generated more misunderstandings because different manufacturers have given widely different flavour assessments of the same samples. That is to some extent understandable because every manufacturer has different processing conditions and recipes, however, it is of little real advantage to the scientists in cocoa producing countries. Comparable data is needed. Recent work has enabled proposals to be made for standard methodologies on Sample Preparation and Taste Testing for Flavour. These are attached as Appendices to the last article in this Issue of the Cocoa Growers' Bulletin. We hope that readers will find these and the other articles on flavour useful in the years to come.

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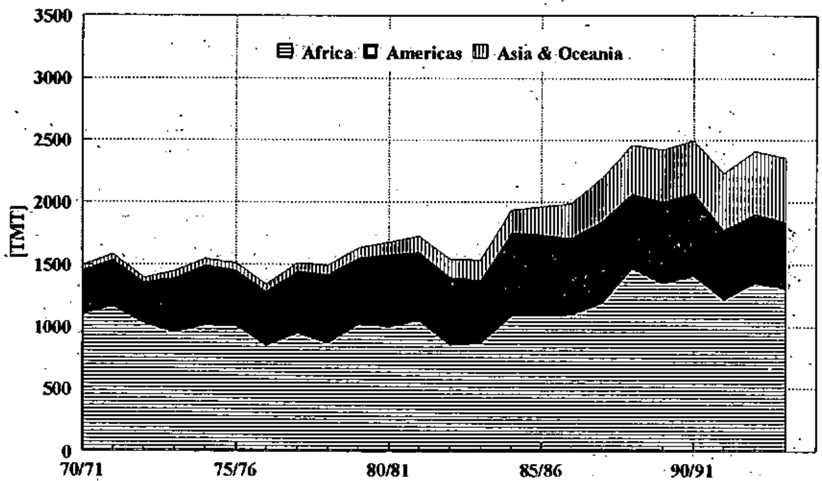
## REVIEW OF PRODUCTION, CONSUMPTION, STOCKS AND PRICES

**S.A.Wakeling**
**(June - September 1994)**

### PRODUCTION

E.D. & F.Man Limited Cocoa Market Report No.350 reported that World production in 1993/94 would be 2,359 TMT ('000 tonnes), which would be 2.2% down on the 2,411 TMT in 1992/93. The 1993/94 production from the Ivory Coast is set to reach 800 TMT, representing over one third of the World's cocoa. The crops in Brazil and Malaysia are falling as the low prices of the late 1980s and early 1990s have taken their affect on the higher cost producers. Of the origins, only Indonesia shows production continuing to surge ahead as a result of new plantings made during the latter half of the 1980s.

**WORLD COCOA PRODUCTION**

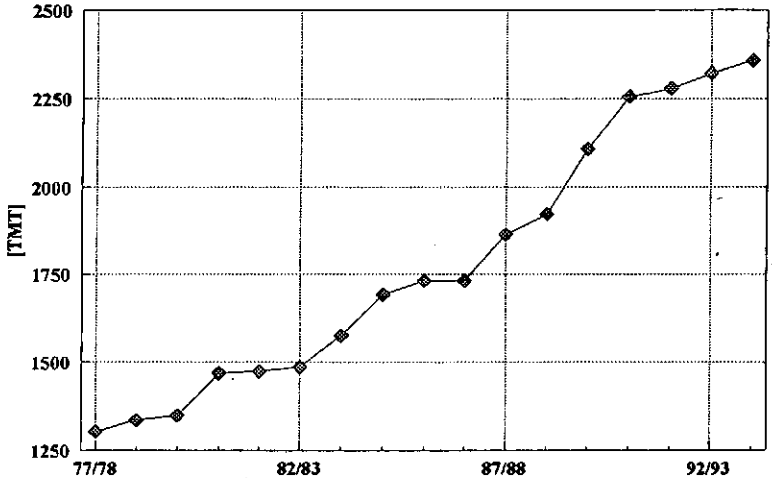



**Source:** E.D. & F.Man Limited, Cocoa Market Report No.350.

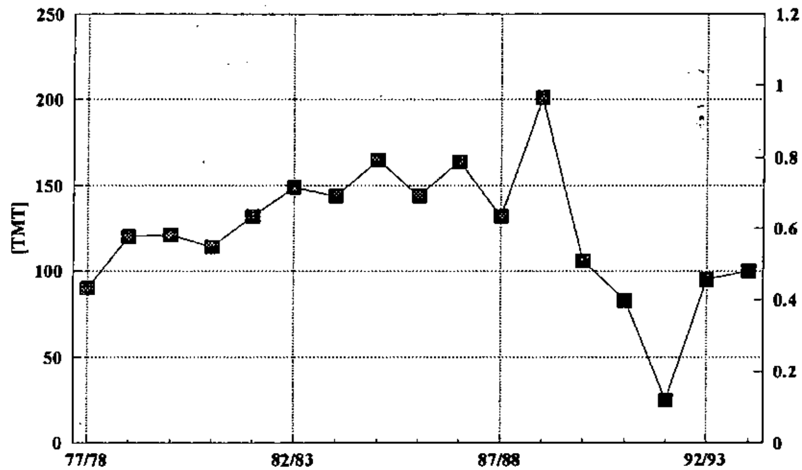
### CONSUMPTION

E.D. & F.Man Limited Cocoa Market Report No.350 reported that World cocoa consumption (as measured by World grind) was set to rise to 2,457 TMT in 1993/94, an increase of 1.7% on 1992/93. The largest consumers, Germany and the United States, have seen a slow down in chocolate production in 1994, though some of this can be attributed to the unusually hot weather during the 1994 summer in the Northern hemisphere. In the Former Soviet Union (FSU) the growth in the import of chocolate products has slowed down, but they are still ahead of 1993.

**GRIND - THE WORLD LESS FSU/USSR**




**GRIND - FSU/USSR**




**Source:** E.D. & F.Man Limited, Cocoa Market Report No.350.

## WORLD COCOA PRODUCTION DATA

### Reproduced from E.D. & F.Man Limited Cocoa Market Report No.350 (September 1994)

| | 1988/ 1989 | 1989/ 1990 | 1990/ 1991 | 1991/ 1992 | 1992/ 1993 | 1993/ 1994 (i) |
|---|---|---|---|---|---|---|
| Cameroon | 129 | 121 | 107 | 108 | 92 | 95 |
| Ivory Coast | 840 | 718 | 769 | 724 | 785 | 800 |
| Ghana | 300 | 295 | 293 | 243 | 312 | 250 |
| Nigeria | 160 | 170 | 170 | 110 | 130 | 130 |
| Togo | 8 | 9 | 9 | 4 | 3 | 4 |
| Others | 33 | 35 | 34 | 27 | 25 | 28 |
| **Total Africa** | **1470** | **1348** | **1409** | **1216** | **1347** | **1307** |
| | | | | | | |
| Brazil | 336 | 355 | 379 | 296 | 294 | 265 |
| Colombia | 50 | 50 | 52 | 49 | 50 | 50 |
| Ecuador | 87 | 101 | 106 | 82 | 69 | 80 |
| Mexico | 42 | 43 | 43 | 45 | 50 | 46 |
| Peru | 12 | 13 | 11 | 11 | 11 | 11 |
| Venezuela | 10 | 14 | 16 | 15 | 16 | 16 |
| Others | 10 | 12 | 11 | 10 | 10 | 10 |
| **Total C. and S.America** | **547** | **588** | **618** | **508** | **500** | **478** |
| | | | | | | |
| Dominican Rep. | 43 | 57 | 42 | 48 | 52 | 55 |
| Others | 8 | 10 | 8 | 9 | 8 | 8 |
| **Total West Indies** | **51** | **67** | **50** | **57** | **60** | **63** |
| | | | | | | |
| Indonesia | 102 | 115 | 145 | 167 | 223 | 250 |
| Malaysia | 223 | 241 | 225 | 225 | 224 | 205 |
| Papua New Guinea | 48 | 41 | 33 | 41 | 39 | 38 |
| Others | 21 | 20 | 20 | 18 | 18 | 18 |
| **Total Asia and Oceania** | **394** | **417** | **423** | **451** | **504** | **511** |
| | | | | | | |
| **WORLD TOTAL** | **2462** | **2420** | **2500** | **2232** | **2411** | **2359** |
| | | | | | | |
| % change in production from previous season | 12.2 | -1.7 | 3.3 | -10.7 | 8.0 | -2.2 |

**(i) Forecast.**
**Note: All figures in Thousand Metric Tonnes (TMT).**
**Some figures may not add due to rounding.**

## WORLD COCOA CONSUMPTION DATA

**Reproduced from E.D. & F.Man Limited Cocoa Market Report No.350 (September 1994)**

| | 1988/ 1989 | 1989/ 1990 | 1990/ 1991 | 1991/ 1992 | 1992/ 1993 | 1993/ 1994 (i) |
|---|---|---|---|---|---|---|
| France | 44 | 59 | 70 | 67 | 80 | 91 |
| Germany (Fed. Rep) | 244 | 273 | 295 | 306 | 305 | 306 |
| Italy | 46 | 51 | 56 | 62 | 58 | 62 |
| Netherlands | 234 | 241 | 268 | 294 | 309 | 333 |
| United Kingdom | 112 | 120 | 145 | 153 | 169 | 169 |
| Others | 140 | 151 | 144 | 145 | 143 | 150 |
| **Total Western Europe** | **820** | **895** | **978** | **1027** | **1064** | **1111** |
| FSU/USSR | 201 | 106 | 83 | 25 | 95 | 90 |
| Other Eastern Europe | 105 | 89 | 83 | 86 | 78 | 78 |
| **Total Eastern Europe** | **306** | **195** | **166** | **111** | **173** | **168** |
| Ivory Coast | 110 | 111 | 115 | 108 | 100 | 105 |
| Others | 64 | 68 | 55 | 67 | 65 | 72 |
| **Total Africa** | **174** | **179** | **170** | **175** | **165** | **177** |
| Brazil | 210 | 239 | 280 | 221 | 222 | 230 |
| United States | 237 | 265 | 265 | 307 | 326 | 312 |
| Others | 175 | 195 | 208 | 190 | 187 | 178 |
| **Total America** | **622** | **699** | **753** | **718** | **735** | **720** |
| Malaysia | 47 | 72 | 77 | 87 | 99 | 102 |
| Others | 155 | 175 | 195 | 186 | 180 | 180 |
| **Total Asia and Oceania** | **202** | **247** | **272** | **273** | **279** | **282** |
| **WORLD TOTAL** | **2124** | **2216** | **2339** | **2304** | **2417** | **2457** |
| % change in grindings from previous season | 6.3 | 4.3 | 5.6 | -1.5 | 4.9 | 1.7 |

**(i) Forecast.**

**Note: All figures in Thousand Metric Tonnes (TMT).**
**Some figures may not add due to rounding.**
**From 1990/91, Germany includes East and West Germany.**

## STOCKS

E.D. & F.Man Limited in their Cocoa Market Report No.350 are forecasting a further deficit for 1993/94. After seven years of surpluses from 1984/85 to 1990/91, the last three years have seen deficits, though not enough to substantially reduce the large World stocks that have built up during the 1980s.

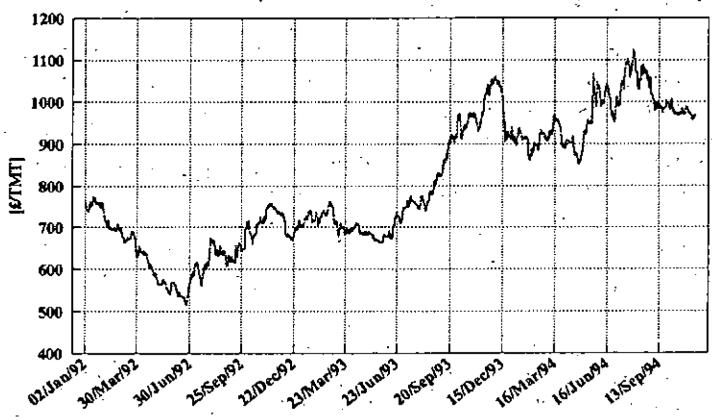
### WORLD COCOA STOCK DATA

**Reproduced from E.D. & F.Man Limited Cocoa Market Report No.350 (September 1994)**

| | 1988/ 1989 | 1989/ 1990 | 1990/ 1991 | 1991/ 1992 | 1992/ 1993 | 1993/ 1994 (i) |
|---|---|---|---|---|---|---|
| Stock change | 313 | 180 | 136 | -94 | -30 | -122 |
| Closing stocks **(including buffer stock)** | 1141 | 1321 | 1457 | 1362 | 1333 | 1211 |
| Stock/consumption ratio **(including buffer stock)** | 0.54 | 0.6 | 0.62 | 0.59 | 0.55 | 0.49 |

**(i) Forecast.**
**Note: All figures in Thousand Metric Tonnes (TMT).**

**COCOA PRICES - LONDON TERMINAL MARKET - 2ND POSITION**



# A REVIEW OF RESEARCH TO IDENTIFY THE ORIGINS OF COCOA FLAVOUR CHARACTERISTICS

**J.F.Clapperton***

## INTRODUCTION

Since the mid 1970s, global cocoa production has almost doubled to a figure now of around 2.4 million tonnes per annum (Smith, 1994). Almost all of the increased production has come from Cote d'Ivoire, Indonesia and Malaysia. Less than 5% of the increase has come from Ghana which earlier had set the industrial flavour standard for bulk cocoa. The result has been a marked divergence in flavour away from Ghanaian quality to supplies with less cocoa flavour and more pronounced acidity. Anticipating those trends, UK manufacturers initiated research studies in Ghana, Malaysia and Cote d'Ivoire to discover why the flavours differed and how to bring them closer to the Ghanaian standard. A project was undertaken with the local authorities in Cote d'Ivoire from 1982-86. It marked an important change in direction of the research from detailed analyses of the composition of the products to studies of field practices which producers were able to test and apply, and has led to a much better understanding of the origins of cocoa flavour characteristics in terms of the effects of planting materials and methods of primary processing. The purpose of this review is to put the most recent information in perspective with the results of the earlier studies and various recommendations that have been given for flavour improvement. Views have changed with time as a broader picture of the subject has emerged and a better understanding of it is obtained. Analytical procedures and disciplines which have contributed to our understanding should now be absorbed so that they may become an integral part of future research studies.

The key development has been the use of analytical and expert sensory evaluation as, indeed, was recommended by Carr and Dougan (1977) and Carr et al. (1980) at the outset. The following extract is from their 1980 report. "It seems to us that acid tainted chocolate may not all be from the same cause because it is sometimes described as acidic and sometimes as fruity. It therefore needs the application of a flavour profile with the necessary vocabulary. When an expert panel of tasters has decided what is acidic chocolate and what is not, then a comparison between the two kinds can be made and the substance identified. Having identified the substance the opportunity for ascertaining the cause is much greater".

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## RESULTS AND DISCUSSION

### Use of Flavour Profile Analysis, Results and Interpretation

A project carried out by the Food Research Institute at Norwich (FRIN), UK provided the first clear indication of the relative effects of post-harvest processing and country of origin on cocoa flavour. Results have been published by FRIN (Davies et al., 1991) but until now have not received public comment or explanation from the industry. Cocoas from Brazil, Malaysia and West Africa were tasted as plain chocolates by panels of up to 20 assessors recruited and trained by FRIN. A profiling method was used to characterise the flavours. Maps of the flavours (Figures 1 and 2) were made using the results of principal components analysis of the characterisation data. The first component (PC1) used to make both maps, separated cocoas with well developed cocoa flavour from others with either bitter and astringent tastes, typical of under-fermentation, or acid tastes. Fruity flavours were associated with acid taste. Samples with distinct cocoa flavours were described also as fragrant/floral. The second component (PC2) used to make the map in Figure 1. This separated cocoas with acidic and fruity flavours from those with either bitter and astringent tastes or hammy flavours. The third component (PC3) used to make the map in Figure 2 contrasted bitter and astringent tastes with hammy or spoiled flavours caused by over-fermentation or smoke contamination.

**FIGURE 1: PRINCIPAL COMPONENTS ANALYSIS OF FLAVOUR CHARACTERISATION DATA. PC1 VS PC2**

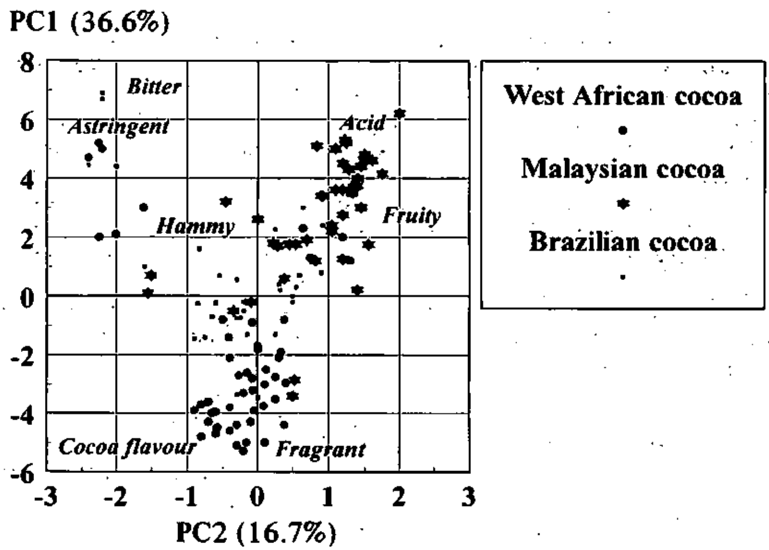
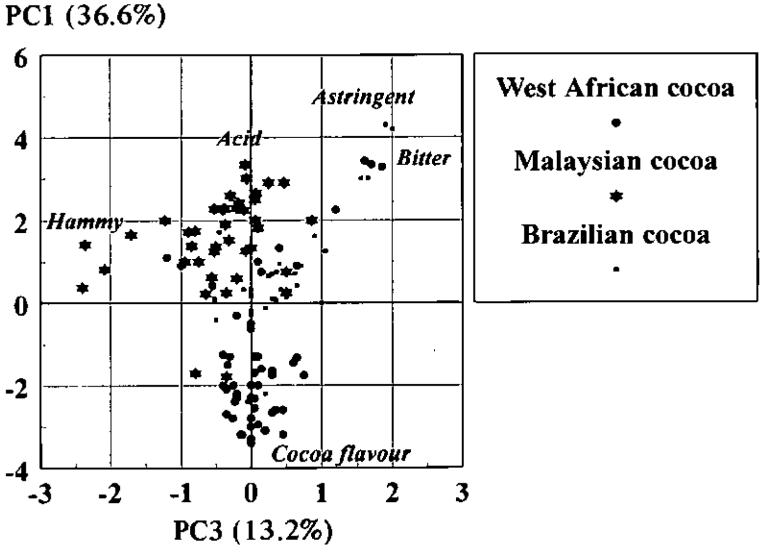


FIGURE 2: PRINCIPAL COMPONENTS ANALYSIS OF FLAVOUR CHARACTERISATION DATA. PCI VS PC3




Cocoas with known processing histories were used to interpret the flavour differences. The four samples of West African cocoa which were plotted among the Malaysian samples (Figure 1) were prepared using Malaysian conditions of post-harvest processing, ie. deep box fermentation with a four step cascade, followed by fast drying at 60°C. Corresponding samples from the same farm which were fermented and dried according to normal West African practices were centred in the group of West African cocoas. The two samples of Malaysian cocoa that are close to the main group of West African cocoas were from trials carried out by Lewis and Lee (1986) in which Malaysian cocoa was processed using pod storage for 7 to 10 days followed by shallow box fermentation for 5 days with a single turn at the end of the second day. After fermentation these cocoas were sun-dried. The flavours of West African and Malaysian cocoas could therefore be moved in either direction depending on the conditions of post-harvest processing. Flavour appeared therefore to be process driven rather than geographical in origin.

Pulp reduction by pressing prior to fermentation, which had been applied to a number of the cocoas from Malaysia, was less effective in changing the flavour. Cocoas which were known to have received that treatment could not be separated from the rest of the Malaysian samples, other than those already discussed. Pressing was recommended by Carr et al., (1980) for further investigation and development as a way of reducing the acidity of Malaysian cocoa.

Malaysian cocoas which were the least acidic (as measured instrumentally) were no more acceptable than the others in terms of West African flavour quality, which underlines the risk of placing too much emphasis on a single instrumental-analytical parameter without sufficient sensory-analytical support. Physical acidity, as indicated by pH, can be reduced by extended fermentation, but at the risk of putrefaction and the development of off-flavours. Attempts to produce putrid off-flavours by deliberate over-fermentation, in order to provide flavour references for taste panel training, were successful when cocoas were fermented for 12 days, but only when the fermentations were turned after every two days. Off-flavours were not produced when the 12 day fermentations were turned only once at the end of the second day (Verhagen and Indranada, 1992). On balance, acid taste is a lesser evil than putrefaction. The former can be reduced or eliminated by processes used by manufacturers, although always at a price and at considerable risk to product quality, whereas the latter defect makes beans, butters and powders virtually worthless.

Pulp reduction by pressing prior to fermentation benefits the producer by reducing the time for production of beans. Because there is less pulp to remove, fermentation time can be reduced and the beans can be dried more quickly, thereby easing capacity problems during crop peaks and saving also on the capital cost of equipment. Pulp reduction by pressing is more likely to have improved flavour by marginally reducing putrid off-flavours than by correcting excessively acid taste.

**Other Reasons for Flavour Differences**

If it were possible to go back in time and provide Carr et al., (1980) with an expert taste panel and the above information that they desired, they would surely have placed less emphasis on differences in pulp volume and condition and interpreted other effects that they had observed in different ways. Concerning the effects of planting materials they stated that "chemical and microbiological studies in Ghana and Malaysia can only lead to the proposition that the Amazon hybrid material itself is responsible for the acidity effect". Recent studies have shown that flavours developed from different planting materials are clearly distinguishable and differ in cocoa flavour intensity, acid taste, bitterness, astringency and fruity/floral notes (Clapperton et al., 1991, 1994a). These are some of the flavour effects which Carr et al., (1980) recognised but were unable to assign. They are in fact characteristic of several of the genetic materials which were introduced from Trinidad during the early 1960s and used extensively in plant breeding programmes and for seed production in Malaysia. The majority of these dominant flavour characteristics are heritable (Clapperton et al., 1993; 1994b). The planting materials developed for commercial production in Malaysia are by no means inferior to those grown in Ghana, but they are different and produce distinctly different flavours. The most important point in connection with the present discussion is that the flavour differences between planting materials reside in the different compositions of the cotyledons and are unaffected by gross differences in pulp composition (Clapperton, 1994; Clapperton et al., 1994c).

Storing pods for up to 12 days before breaking them to separate the wet beans for fermentation has for some time been part of post-harvest treatments recommended to improve the flavour of Malaysian cocoa (Lewis and Lee, 1986; Duncan et al., 1989; CAOBISCO, 1990). During storage, the compositions of both pulp (Meyer et al., 1989) and cotyledons (Clapperton et al., 1992) are altered. Shorter periods of post-harvest storage followed by partial removal of pulp by spreading the wet beans to dry in the sun, or by air-blasting, have also been recommended (Biehl et al., 1990; Said et al., 1990). Carr et al., (1980) had observed the same effects on pulp volume and suggested that the practice in Malaysia of harvesting the pods and separating the wet beans without delay might contribute to acid taste. On smaller farms and with family labour in Ghana it might take 7 days or more to gather sufficient pods to provide 250-500 kg of wet beans for fermentation. There, delays between harvesting and breaking are by necessity rather than design.

In commercial scale trials in Malaysia in which the recommendations by Duncan et al., (1989) were followed as closely as possible, cocoa flavour was improved after pods had been stored for 9 days before breaking and acid taste was reduced by drying the fermented beans more slowly at lower temperatures (Arikiah et al., 1994). The increases in cocoa flavour were not attributable to the changes in pulp volume effected by the pod storage treatments. Later trials at BAL Plantations Sdn Bhd showed that effects of pod storage on flavour differed markedly between genotypes (Clapperton et al., 1994c). The differences in flavour were independent of differences in pulp volume and condition but corresponded closely to differences in the polyphenol compositions of the cotyledons before and after post-harvest storage. Polyphenols which were altered, contributed directly to astringency which in certain of the genotypes was markedly reduced by the pod storage treatments. There was a high inverse correlation between scores for astringency, and cocoa flavour intensity. Again it was the composition of the cotyledons, not the condition of the pulp, that seems to be linked to these differences in flavour.

**The Cause of Excessive Acidity and How to Avoid It**

Organic acids formed during pulp fermentation are clearly the source of the acidity. The main concerns, however, are not how they are formed and enter the beans, but how they interact with the cotyledons and, most importantly, how they are removed.

When beans are dried slowly after fermentation, ideally in the sun, the acids migrate from the cotyledons to the shells where they are lost by evaporation or decomposition while the beans remain moist and permeable (Duncan et al., 1989). Under conditions of fast drying at higher temperatures the acids are concentrated in the cotyledons causing sharp and acid off-flavours. Cocoas from the trials at United Plantations (Arikiah et al., 1994) were tasted against samples of Malaysian cocoa from standard production in a ring test involving 18 independent taste panels from European cocoa and chocolate manufacturers and research institutes. Every single panel confirmed that the cocoas which had been dried more slowly were less acidic (Clapperton, 1993). Trials carried out in Brazil showed also that acidity was reduced by sun drying and by slower mechanical drying (Dias and Avila, 1993). As a result, sun drying has been installed as standard practice for full scale production on some large estates in Indonesia (Chok, 1993).

In another approach in Malaysia, the acid taste has been reduced and cocoa flavour improved by a process in which beans were depulped and partially dried prior to fermentation (Beh and Pilkington, 1994). A two stage fermentation in shallow boxes was used to achieve aerobic fermentation, but with only one turn after 18 hours. After fermentation, the beans were fast dried at 60 to 70°C. A detailed and thorough analysis of the process showed that both acid production and the degree of modification of the beans (fermentation index) were reduced. The lower fermentation index was consistent with the presence of a slightly raw/beany flavour indicative of under-fermentation. In terms of overall acceptance, a suggestion of under-fermentation was clearly preferred to excess acidity. The overall flavour was on par with West African flavour but slightly less than Ghanaian flavour. The process was interpreted as providing the correct rate of acidification for the formation of flavour precursors by proteolysis (Biehl et al., 1985). Certain degradation products of cocoa storage proteins are believed to be the materials which give cocoa its unique flavour quality (Biehl et al., 1982, 1985; Voigt et al., 1994). Irrespective of which constituents are involved in flavour development, the process emphasises the degree of acid production that is necessary and sufficient to modify the cotyledons rather than the removal of excess acid by slow drying.

**Direction of Further Research**

A recent review of studies of the organic acids of cocoa beans by Jinap (1994) shows the degree of attention and detailed research the subject has received. Much of the detail is now only of background interest to the acidity problem because simple and effective technical solutions are available. Interest might turn now to how acidification of the beans affects the course of normal flavour development and the flavour differences between planting materials, but will set new challenges with an increased degree of difficulty. Manufacturers agree about the off-flavours, which are unwelcome and are best avoided (CAOBISCO, 1990). However, characteristics of normal cocoa flavours differ between manufacturers and will be liked by some manufacturers and disliked by others depending on their traditional markets. In the future, it is likely to become more important to identify and deliver the specific flavour qualities that manufacturers require and careful checking and cross-checking of the flavours among researchers, producers and manufacturers will be necessary. Over recent decades, there have been contradictory methods for flavour assessment and a lack of consistency between manufacturers. Recent work has produced broad agreement within the industry and protocols are now available.

**Experimental Protocols**

Procedures for sample preparation and taste testing are included in the paper as the Effects of Planting Materials on Flavour in this issue of the Cocoa Growers' Bulletin (Clapperton et al., 1994c). In this work, the procedures for fermentation and drying have been deliberately kept simple to allow uniform application in different locations and environments and were designed to avoid the various flavour defects discussed here. It is hoped that the procedures described in these protocols will now be adopted by everyone who is preparing samples of cocoa beans for flavour assessment.

**Instrumental-Analytical Data**

Instrumental analyses have been a very small part of the work described here and elsewhere in this issue. Where they have been used it has been to confirm or elucidate effects established by sensory evaluation from repeated sample preparation. Titratable acidity has been related to differences in acid taste resulting from different drying treatments (Beh and Pilkington, 1994; Dias and Avila, 1993; Duncan et al., 1989). Estimates of lactic acid have been used to monitor the migration of organic acids from cotyledons to shells during drying (Arikiah et al., 1994). Differences in polyphenol composition have been related to differences in astringency between genotypes (Clapperton et al., 1992). In all of these cases there is no doubt that the constituents relate directly to the respective sensory characteristics. With other constituents which may either be cocoa flavour precursors or part of the flavour itself (eg. pyrazines, aldehydes and various sulphur containing compounds) the relationships are much more circumstantial and a great deal more work needs to be done in order to establish cause and effect. Flavour is a perceived phenomenon and demands the use of reliable and validated sensory evaluation.

## SUMMARY AND CONCLUSION

There is now a better understanding of the origins of cocoa flavour quality. Planting materials and the use of appropriate conditions of post-harvest processing determine the characteristics of normal flavour development, as opposed to off-flavours which result from defective processing. Fermentation initiates the modification of the bean and realises the genetic potential for flavour development. Conditions of fermentation and drying affect the final acidity.

Recommendations for flavour improvement given by various manufacturers over the past 10 years can be reconciled within that framework. Originally, Mars, via the report by Lewis and Lee (1986), recommended the use of pod storage in conjunction with shallow box fermentation. The Sime/Cadbury work confirmed these recommendations and extended them to include slow drying (Duncan et al., 1989). Mars, via the trials with United Plantations, confirmed that slow drying reduced acidity, and observed that the effect of shallow box fermentation was small compared to the effects of pod storage and slow drying (Arikiah et al., 1994). The current project at BAL Plantations Sdn Bhd being funded by the Biscuit Cake Chocolate and Confectionery Alliance (BCCCA) has shown that good cocoa flavour can be generated from several genotypes without pod storage (Clapperton et al., 1992, 1994c). Hershey (Rita, 1993) recommended no pod storage, deep box fermentation and slow drying. Nestle/Golden Hope (Beh and Pilkington, 1994) recommended partial depulping, shorter fermentation and fast drying. While the last is at odds with the other recommendations it does fit within the overall framework and understanding of flavour development, the key considerations being the extent of acid formation during fermentation and the removal of excessive acidity during subsequent drying. All the major manufacturers are giving much the same overall direction but with different emphasis on certain parts of the process depending, presumably, on their own particular requirements.

There is no reason why the findings should not be extended to all origin countries in order to improve flavour quality at source. An immediate extension has been to Sulawesi (Duncan and Veldsman, 1993) where there is a considerable need for flavour quality improvement.

The same considerations relating to normal flavour development and the avoidance of off-flavours are applicable also to fine cocoas discussed (Fowler, 1994). In that group, genetic differences and effects are likely to be even more pronounced together with marked interactions between planting materials and fermentation treatment. Traditionally, fine cocoas have required shorter fermentation than bulk cocoas.

**REFERENCES**

*Arikiah,A., Tan,Y.P., Sharma,M. and Clapperton,J.F.* (1994) Experiments to Determine Influence of Primary Processing Parameters and Planting Material on the Flavour of Cocoa Beans in Malaysia. Cocoa Growers' Bull., **48**, pp.36-46.

*Beh,B.W. and Pilkington,I.J.* (1994) A New Method for Processing Cocoa Beans. Proceedings of International Planters' Conference, pp.441-450.

*Biehl,B., Wewetzer,C. and Passern,D.* (1982) Vacuolar (storage) Proteins of Cocoa Seeds and their Degradation during Germination and Fermentation. J. Sci. Food Agric., **33**(12), pp.1291-1304.

*Biehl,B., Brunner,E., Passern,D., Quesnel,V.C. and Adomako,D.* (1985) Acidification, Proteolysis and Flavour Potential in Fermenting Cocoa Beans. J. Sci. Food Agric., **36**(7), pp.583-598.

*Biehl,B., Meyer,B., Said,M.B. and Samarakoddy,R.J.* (1990) Bean Spreading: A Method for Pulp Pre-conditioning to Impair Strong Nib Acidification during Cocoa Fermentation in Malaysia. J. Sci. Food Agric., **51**(1), pp.35-45.

*Carr,J.G. and Dougan,J.* (1977) The Cocoa Bean Acidity Problem in Malaysia. Cocoa Chocolate and Confectionery Alliance (now BCCCA), London.

*Carr,J.G., Davies,P.A. and Dougan,J.* (1980) Cocoa Fermentation in Ghana and Malaysia Parts I and II, 1979/80. Cocoa Chocolate and Confectionery Alliance (now BCCCA), London.

*CAOBISCO* (1990) Position Statement on Cocoa Quality, March 1990.

*Chok,D.K.K.* (1993) A Case for Sun Drying. Proceedings of First Indonesian Cocoa Conference, Bali, in press.

*Clapperton,J.F.* (1993) Quality Marks. Proceedings of First Indonesian Cocoa Conference, Bali, in press.

*Clapperton,J.F.* (1994) Selecting for Quality. Proceedings of Cocoa Breeders' Workshop, Kuala Lumpur, in press.

*Clapperton,J.F., Yow,S.T.K., Chan,J., Lim,D.H.K., Lockwood,G., Romanczyk,L. and Hammerstone,J.F.* (1991) The Effect of Cocoa Genotype on Flavour. Proceedings of the International Cocoa Conference, Challenges in the 1990s, Kuala Lumpur. Malaysian Cocoa Board, Kota Kinabalu, pp.468-478.

*Clapperton,J.F., Romanczyk,L., Hammerstone,J.F., Yow,S.T.K., Lim,D.H.K. and Lockwood,G.* (1992) Polyphenols and Cocoa Flavour. Proceedings of Meeting of Groupe Polyphenols, **16**(II), pp.112-116.

*Clapperton,J.F., Yow,S.T.K., Lim,D.H.K. and Lockwood,G.* (1993) Genetic Variation in Cocoa Flavour. Proceedings of Eleventh International Cocoa Research Conference, Yamoussoukro, in press.

*Clapperton,J.F., Yow,S.T.K., Chan,J., Lim,D.H.K., Lockwood,G., Romanczyk,L. and Hammerstone,J.F.* (1994a) The Contribution of Genotype to Cocoa (Theobroma cacao L.) Flavour. Trop. Agric. (Trinidad), 71(4), pp.303-308.

*Clapperton,J.F., Yow,S.T.K., Lim,D.H.K. and Lockwood,G.* (1994b) Back to the Future: An Opportunity for Malaysian Cocoa. Proceedings of Malaysian International Cocoa Conference, Kuala Lumpur, in press.

*Clapperton,J.F., Lockwood,G., Yow,S.T.K. and Lim,D.H.K.* (1994c) Effects of Planting Materials on Flavour. Cocoa Growers' Bull., **48**, pp.47-63.

*Davies,A.M.C., Franklin,J.G., Grant,A., Griffiths,N.M., Sheperd,R. and Fenwick,G.R.* (1991) Prediction of Chocolate Quality from Near-infrared Spectroscopic Measurements of the Raw Cocoa Beans. Vibrational Spectroscopy, **2**, pp.161-172.

*Dias,J.C. and Avila,M da G.M.* (1993) Influence of the Drying Process on the Acidity of Cocoa Beans. Agrotropica, 5(1), pp.19-24.

*Duncan,R.J.E. and Veldsman,I.* (1993) A European Chocolate Manufacturers' Experience of Fermented Sulawesi Cocoa. Proceedings of First Indonesian Cocoa Conference, Bali, in press; [Reproduced in this issue of Cocoa Growers' Bulletin, **48**, pp.24-35].

*Duncan,R.J.E., Godfrey,G., Yap,T.N., Pettipher,G.L. and Tharumarajah,T.* (1989) Improvement of Malaysian Cocoa Bean Flavour by Modification of Harvesting, Fermentation and Drying Method - the Sime/Cadbury Process. The Planter, Kuala Lumpur, **65**, pp.157-173.

*Fowler,M.* (1994) Fine or Flavour Cocoas: Current Position and Prospects. Cocoa Growers' Bull., **48**, pp.17-23.

*Jinap,S.* (1994) Organic Acids in Cocoa - A Review. ASEAN Food Journal, **9**(1), pp.3-12.

*Lewis,J.F. and Lee,M.T.* (1986) The Influence of Harvesting, Fermentation and Drying on Cocoa Flavour Quality. The Planter, Kuala Lumpur, **62**, pp.134-140.

*Meyer,B., Biehl,B., Said,M.B. and Samarakoddy,R.J.* (1989) Post-Harvest Pod Storage: A Method for Pulp Pre-conditioning to Impair Strong Nib Acidification during Cocoa Fermentation in Malaysia. J. Sci. Food Agric., **48**(3), pp.285-304.

*Rita,J.G.* (1993) Hershey's Recommendation on the Fermenting and Drying of Malaysian and Indonesian Cocoa. Submitted to Malaysian Cocoa Growers' Council, April, 1993.

*Said,M.B., Jayawardena,M.P.G.S., Samarakoddy,R.J. and Perera,W.T.* (1990) Pre-conditioning of Fresh Cocoa Beans Prior to Fermentation to Improve Quality: A Commercial Approach. The Planter, Kuala Lumpur, **66**, pp.332-345.

*Smith,R.W.* (1994) Cocoa Production Systems: Options and Constraints. Cocoa Growers' Bull., **47**, pp.20-26.

*Verhagen,R. and Indranada,T.K.* (1992) Development of a Cocoa Flavour Library - A joint project between the Biscuit, Cake, Chocolate and Confectionery Alliance, UK and ASKINDO, Indonesia.

*Voigt,J., Biehl,B., Heinrichs,H., Kamaruddin,S., Gaim-Marsoner,G. and Hugi,A.* (1994) In vitro Formation of Cocoa Specific Aroma Precursors: Aroma Related Peptides Generated from Cocoa Seed Protein by Co-operation of an Aspartic Endoprotease and a Carboxypeptidase. Food Chemistry, **49**(2), pp.173-180.

# FINE OR FLAVOUR COCOAS: CURRENT POSITION AND PROSPECTS

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## INTRODUCTION

There has always been a small market for speciality cocoas to meet manufacturers' needs for particular flavours or qualities. These fine or flavour cocoas are mainly used to make premium dark (plain) chocolates and high quality couvertures (coatings) where the special qualities of such cocoas can be fully appreciated. Such cocoa beans frequently attract a premium price on the cocoa market.

There is, however, no universally accepted criterion for distinguishing between fine cocoas and the bulk (or ordinary or basic) cocoas. Fine cocoas currently represent around 5% of the world market. The distinction between these cocoas has frequently become political because fine cocoas have been treated differently in successive International Cocoa Agreements (Anon, 1994). A number of criteria have been suggested or used in the past (Anon, 1991, 1994), including:

- Planting material;
- Environmental effects and post-harvest processing;
- Flavour and colour;
- Method of marketing and existence of a price premium.

These criteria are considered in more detail below.

## CHARACTERISTICS OF FINE OR FLAVOUR COCOAS

### Planting Material

The type of planting material has a major influence on the flavour and colour of the cocoa beans (Clapperton, 1993). Traditionally, fine or flavour cocoas have come from Criollo or Trinitario trees and bulk cocoas from Forastero trees (Wood, 1978, 1985). However, there are exceptions. Arriba is a fine cocoa that comes from the Nacional variety grown in Ecuador. Nacional is usually considered a Forastero type although recent studies have suggested that it may be closer to a Criollo type (Enriquez, 1993). Another exception is Cameroon which produces bulk cocoa despite having a largely Trinitario tree population. We can conclude that while planting material is important, it cannot be used alone to distinguish between fine and bulk cocoas.

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**Environmental Effects and Influence of Post-harvest Processing**

Environmental effects (mainly soil and climate) and methods of post-harvest processing have been proposed as being responsible for the Arriba flavour of Ecuadorian beans (Enriquez, 1993; Wood and Lass, 1985). Other work (Clapperton, 1994) indicates that the same genetic material planted in different environments exhibits similar flavour characteristics when processed in a similar manner.

Post-harvest processing is critical for all cocoas and is essential for the development of cocoa flavour. It is also the stage where many of the quality faults occur (eg. smoky or putrid off-flavours, mouldy beans). Post-harvest processing must be done well and consistently according to locally developed and accepted practices. Fine cocoas are often given different conditions of post-harvest processing. Certain types (eg. Java light-breaking and Ecuador Arriba beans) need only very short fermentations whereas others (eg. Trinidad) have longer fermentations.

Although clearly important, we cannot use either environmental effects or methods of post-harvest processing to help determine whether a cocoa should be classed as a fine or flavour cocoa or not. However, poorly processed cocoa with quality faults **cannot** be used as a fine cocoa.

**Flavour and Colour**

Manufacturers only buy fine or flavour cocoas if they provide special or different characteristics which are desirable in their products. The most usual reason for using fine cocoas is flavour. Unfortunately, flavour is a very subjective criterion and manufacturers have different requirements.

The significance of colour should not be ignored (Anon, 1991), in particular "light or white-breaking" beans (see below). The pressing industry uses certain origins of beans to produce reddish coloured cocoa powders, but these origins are regarded as bulk cocoas.

One good criterion for deciding whether a cocoa is special is whether the flavour (or colour) of the beans is sufficiently distinctive that it cannot be substituted by another readily available origin. This is likely to determine whether a manufacturer will be prepared to pay a premium or not. However, it should be borne in mind that manufacturers' blends and requirements may be flexible depending on the costs of the raw materials and sales of the finished products.

**Method of Marketing and Existence of a Price Premium**

Unlike bulk cocoas, fine cocoas are usually sold on the basis that the buyer can examine a predelivery sample. The manufacturer will then assess the flavour to see if it meets his specific requirements: rejections can be frequent. The consequence of this is that suppliers usually have to hold back-up stocks. This, coupled with sampling and assessment costs, make fine cocoas more expensive to market than bulk cocoas. Therefore fine or flavour cocoas need to be sold for a premium, and not all of the premium will go to the growers.

The payment of a premium by manufacturers over the price of Ghana cocoa should be an objective criterion to distinguish between fine and bulk cocoas. However, as shown by ICCO (Anon, 1994), the premium is highly dependent on supply and demand. Some fine cocoa origins record export prices significantly higher than the bulk cocoa exporting countries, but others had prices that were similar to or even lower than bulk cocoa prices. Premiums can range from being negative (ie. sold at a discount), through a more typical range of 10% to 40%, to more than 100% (Wood, 1978).

## PRODUCTION OF FINE OR FLAVOUR COCOAS

Without a clear agreed definition of fine or flavour cocoas it is impossible to make an accurate estimate of their production level. The countries and the proportion of their production that is considered to be fine cocoa are shown in Table 1. The quantities have been calculated from ICCO figures. Due to variations in production the amounts of fine cocoas should be regarded as a guide. The total figures are mainly influenced by the production levels in Ecuador and whether one considers Mexico to be a partial producer of fine cocoa. In recent years the production of fine cocoas as a percentage of world production has varied from 5.1% to 4.3%.

## TYPES OF FINE OR FLAVOUR COCOAS

Each manufacturer has his own specific requirements but it is possible to identify several broad categories of fine cocoa.

### Ecuador Arriba

About half of the total world tonnage of fine or flavour cocoa is Arriba (Table 1). Good quality Arriba cocoa has a full chocolate flavour with distinctive floral and aromatic spicy notes (Cook, 1982). Some of this flavour has been lost with the use of different planting material. The strongest "Arriba" flavour comes from the traditional Nacional variety in Ecuador. A lot of the cocoa is poorly prepared and the lower grades often sell at a discount to Ghana cocoa.

### Light-breaking Cocoa

Often called Criollo, this cocoa has nib (cotyledon) that is a cream or light brown colour (hence the term: light-breaking cocoa). It has large beans (80 to 90 beans/100g) with a low fat content and mild, nutty cocoa flavour (Anon, 1991). A very small quantity is now produced in Mexico, Venezuela and Samoa. There is a larger production from Java (Table 1) but Java lightbreaking cocoa is not botanically a pure Criollo. It is a white bean version of a Trinitario that has some similarities with Criollo cocoa (Wood and Lass, 1985).

**TABLE 1: PRODUCTION OF FINE OR FLAVOUR COCOAS FOR THE 1990s**

| Country | Production | Proportion of Fine Cocoas | | Approximate Fine Cocoa Tonnage |
|---|---|---|---|---|
| | ICCO (1992/93) '000 tonnes | ITC Unctad (1991) % | ICCO (1994) % | (ICCO) |
| Belize | 0.1 | 100 | 0 | 0 |
| Colombia | 50.0 | 25 | 25 | 12,500 |
| Costa Rica | 3.0 | 50 | 25 | 750 |
| Dominica | 0.05 | 100 | 100 | 50 |
| Ecuador | 67.4 | 75 | 75 | 50,550 |
| Grenada | 0.9 | 100 | 100 | 900 |
| Indonesia | 240.0 | 10 | 5 | 12,000 |
| Jamaica | 2.2 | 100 | 100 | 2,200 |
| Madagascar | 4.0 | 0 | 50 | 2,000 |
| Mexico | 50.0 | 25 | 0 | 0 |
| Papua New Guinea | 38.8 | 30 | 25 | 9,700 |
| Saint Lucia | 0.1 | 100 | 100 | 100 |
| St Vincent & Grenadines | -- | 100 | 100 | -- |
| Samoa | -- | 100 | 100 | -- |
| Sao Tome & Principe | 3.0 | 0 | 25 | 750 |
| Sri Lanka | 1.4 | 100 | 25 | 350 |
| Surinam | -- | 0 | 100 | -- |
| Trinidad & Tobago | 1.7 | 100 | 100 | 1,700 |
| Venezuela | 15.5 | 100 | 50 | 7,750 |
| **Total Fine Cocoa (tonnes)** | | | | **101,300** |
| **Percentage of Total World Production of Cocoa 1992/93 which was 2,376,200 tonnes** | | | | **4.3%** |

**Source:** Anon (1991, 1994a)

**Caribbean Trinitario**

This category includes Trinitario cocoas from Trinidad, Grenada and some of the other Caribbean islands as well as part of the production from Venezuela and Colombia. It is characterised by a full cocoa flavour with pleasant ancillary flavours such as molasses, liquorice, caramel and raisin. These cocoas are regarded by some manufacturers as superior cocoas of the highest quality (Beckett, 1994).

**Other Trinitarios**

This is a group with medium cocoa flavour, pronounced fruitiness and often some acidity. Cocoas from Papua New Guinea and Madagascar come into this category.

## USE OF FINE COCOAS BY THE INDUSTRY

The largest market for fine cocoas is USA, followed by Japan, Germany, Switzerland, France and UK (Anon, 1991).

Often fine cocoas from several origins will be blended, sometimes with bulk cocoas. This serves to reduce the dependence of the manufacturer on a specific origin. The precise bean blends used by each manufacturer are usually kept secret.

Many products containing fine cocoas are premium priced and occupy specialist niches in the confectionery market. For example, in Europe, particularly in France, there is a market for dark chocolate with high cocoa solids (60% to 70%). Some of these products have the origins of the cocoa beans and the planting materials listed on the wrapper. It is likely that special niche markets for chocolate containing fine cocoas will continue, but the tonnage of beans required for these markets will remain at a very modest level.

Fine cocoas are rarely added to milk chocolates. This is because the special flavour found in fine cocoas would be masked by the taste of the milk ingredients. Fine cocoas can be used to make milk chocolates but their value would be assessed by the buyer on the yields of nib and the percentage of cocoa butter not on the special flavour characteristics possessed by those beans. Manufacturers of milk chocolates are not prepared to pay a premium for fine cocoa beans based on flavour: they would only pay a premium if it was based on yields (Scheu, 1994).

A similar argument applies to the use of fine cocoas by the pressing industry to produce cocoa powder and cocoa butter. A producing country growing fine or flavour cocoas which has its own pressing industry could use locally produced cocoa, but when premiums were high, these fine cocoas could be exported with advantage and cheaper bulk cocoas imported to maintain production at the factory.

## PROSPECTS AND ADVICE TO GROWERS

There is a small market for fine or flavour cocoas in speciality products. These can be sold at high prices, which is needed to cover the higher marketing, sales, processing and material costs. This situation is likely to continue well into the future.

Fine or flavour cocoas are unlikely to be incorporated into everyday products because of:

- inconsistent and insufficient supply;
- variable levels of premiums;
- large capacity of modern processing plants which makes handling of small quantities of fine cocoas difficult;
- processing developments and addition of other ingredients may reduce the flavour benefits that can be achieved by using fine cocoas.

**Advice to Growers**

It is not possible to give advice that would apply to the various situations around the world. Here we can suggest a number of questions and issues that should be addressed prior to deciding whether to continue with, expand or enter into the production of fine or flavour cocoas.

- What is the market for the particular type of fine or flavour cocoa?
- How is it being traded? Who is buying it?
- What is it being used for? What are the prospects for increased usage?
- What are the levels of premium being paid and what proportion reaches the grower?
- Would additional supply reduce these premiums?
- How are you going to market the cocoa?
- Could the cocoa be sold as a bulk cocoa at reasonable prices?
- Can you negotiate long term contracts that incorporate a premium?

Only after the grower has confirmed that a reasonable market exists for his particular fine or flavour cocoa should he consider factors such as costs of production and post-harvest processing as well as availability of planting materials and labour.

Given the levels and unpredictability of premiums, the field performance of fine cocoa varieties must be as good as the available bulk varieties. The strategy for existing fine cocoa producers should be to breed higher yielding varieties with reasonable levels of nib yield and cocoa butter whilst maintaining the special flavour characteristics attractive to manufacturers. It is important to check with the existing users of the fine or flavour cocoa beans that flavour is not being degraded unknowingly.

**REFERENCES**

*Anon* (1991) Fine or Flavour Cocoa. An Overview of World Production and Trade. International Trade Centre, UNCTAD/GATT, Geneva.

*Anon* (1994) Fine or Flavour Cocoa (A background paper prepared by the ICCO Secretariat) ICC/48/9, April 1994. Report by the Chairman of the Working Group on Fine or Flavour Cocoa ICC/48/10, June 1994.

*Anon* (1994a) Quarterly Bulletin of Cocoa Statistics, September 1994. ICCO Secretariat, International Cocoa Organisation, London.

*Beckett,S.T.* (1994) Industrial Chocolate Manufacture and Use. Second Edition, Blackie A&P London.

*Clapperton,J.F.* (1993) Assessment of Cocoa Flavour and Fat Content. Proceedings of International Workshop on Conservation, Characterisation and Utilisation of Cocoa Genetic Resources in the 21st Century, September 1992. Cocoa Research Unit, University of the West Indies, pp.111-120.

*Clapperton,J.F.* (1994) Visit Report November 1994. The BCCCA/BAL Estate Cocoa Flavour and Quality Project. BCCCA London.

*Cook,R.L.* (1982) Chocolate Production and Use (revised by *Meursing,E.H*). Harcourt Brace Jovanovich Inc. New York.

*Enriquez,G.A.* (1993) Characteristics of Cacao "Nacional" of Ecuador. Proceedings of International Workshop on Conservation, Characterisation and Utilisation of Cocoa Genetic Resources in the 21st Century, September 1992. Cocoa Research Unit, University of the West Indies, pp.269-278.

*Scheu,J.J.* (1994) Fine or Flavour Cocoa. Comments on the background paper of the International Cocoa Organisation. WGFF/1/3 May 1994. International Cocoa Organisation, London.

*Wood,G.A.R.* (1978) Markets for Fine Flavour versus Bulk Cocoas. Cocoa Growers Bull., 27, pp.5-11.

*Wood,G.A.R.* (1985) The Markets for Fine Flavoured versus Bulk Cocoas. The Manufacturing Confectioner, January 1985, pp.45-48.

*Wood,G.A.R. and Lass,R.A.* (1985) Cocoa 4th Edition. Tropical Agricultural Series, Longman Group Limited, London.

# A EUROPEAN CHOCOLATE MANUFACTURERS' EXPERIENCE OF FERMENTED SULAWESI COCOA

**R.J.E.Duncan and I.Veldsman***

## INTRODUCTION

The social and economic requirements of a Sulawesi smallholder are probably not very different from those of a West African smallholder. It is likely that given similar marketing constraints on their products, many of their actions in dealing with their crops might also be similar.

In West Africa, it is customary for cocoa smallholders to take several days to harvest and collect into one place sufficient pods for a fermentation. They then split the pods and build the fermentation heap one or two days later (Duncan, 1986). These delays are because West African smallholders usually require the help of their family and/or neighbours to harvest, collect and split pods and this source of labour is not always readily available or predictable. After splitting the pods, the wet beans are removed and fermented in the simplest and most convenient way in the traditional heap (Wood and Lass, 1985). The duration of fermentation is between 4 and 6 days and often the beans will not be mixed during this period or at most mixed only once. Finally, after fermentation the West African smallholder has no option but to dry the beans in the sun.

In Sulawesi there are some smallholders who are motivated to ferment their wet beans. A fermentation requires a certain quantity of beans and so these Sulawesi smallholders are faced with similar delays in splitting pods as are faced by the smallholders in West Africa. Therefore, effectively the smallholder who ferments his cocoa in Sulawesi, stores the pods before fermentation in the same way as his West African counterpart. Most Sulawesi smallholders who ferment do so in boxes, although some do use the heap system popular among West African smallholders. Whether in a heap or in a box, it is suggested that fermentations are rarely turned in Sulawesi. Nevertheless, it is difficult to ferment badly as long as the ferments are not left uncovered or allowed to over-ferment which might occur if left more than 7 days. At the completion of fermentation the simplest and cheapest drying technique for smallholders in both West Africa and Sulawesi is sun drying either on mats or on the ground. Therefore, if factors such as planting material, soil, and climate are not dominant in predetermining cocoa flavour potential, "fermented" Sulawesi smallholder cocoa beans collected and "bulked", might be expected to be similar in flavour to West African cocoa.

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To test this hypothesis, Cadbury Ltd was supplied by P.T.Hasfarm Commodity Nusantara (HASCOM) throughout 1991 with samples of bulk, fermented and sun dried Sulawesi smallholder cocoa. At the end of the year a commercial parcel of this cocoa was assembled by HASCOM and shipped to Cadbury Ltd in the UK where it was evaluated in a full scale factory trial. This paper outlines the quality data on the samples supplied by HASCOM during 1991 and the findings of the factory trial.

## MATERIALS AND METHODS

### Collection of Fermented Cocoa Beans

Operating out of a store in Ujung Pandang, HASCOM isolated bags of fermented and sun dried cocoa beans from the parcels delivered to them. The selection of fermented and sun dried cocoa was done by inspecting the beans **in each bag** of a parcel when it arrived at the store and applying the selection criteria shown in Table 1.

**TABLE 1: HASCOM SELECTION CRITERIA FOR FERMENTED AND SUN DRIED COCOA**

* the cocoa in a bag is fairly uniform in appearance
* the cocoa has a moisture content of <7%
  (as measured by Protometer moisture meter test)
* the cocoa has no acid or smokey odours
* the shells are not shrivelled or adhering to the nibs which often occurs when beans are dried
* a cut-test of some beans reveals no slate or mouldy beans and shows a fair degree of brown colour

Deliveries accepted by these procedures were then sorted in the usual way to remove small beans, flat beans and rubbish before being "bulked" and bagged for export. Such selected cocoa was always kept separate from unfermented cocoa which was also being handled in the same warehouse. A number of laboratory samples of 1 kg were prepared and dispatched by air to the UK in sealed polythene bags.

**Evaluation of Cocoa Flavour Quality**

*Small Samples of Beans*

On arrival at Cadbury Ltd each bean sample was made into dark chocolate in a small scale chocolate plant. Chocolates were presented under code (3 digit random number) to a panel of screened and trained tasters familiar with tasting this type of product. On the same panel a second sample of chocolate made from acceptable Ghana beans was also presented under code. The panel was arranged such that no more than 4 chocolate samples were presented at the same time and no panellists received the chocolate samples in the same order.

For each sample each panellist completed a separate tasting form (Figure 1). This contained a list of 22 flavour attributes necessary to describe the flavour of this type of chocolate. The panellist marked the intensity of each flavour on the appropriate line between the anchor points - for "absent" and "extreme". These marks were digitised and analysed using a computer software package (SENPAK) designed for statistical analysis of sensory data whose basis was Analysis Of Variance.

*Liquor from Factory Trials and from 30% Samples*

Cocoa liquors were produced either on a small scale from the 30% bean sample taken when the shipment arrived in the UK port, or in the factory when the beans were processed. These liquors were assessed by paired comparison with a control liquor made from good quality Ghana beans. Panellists were presented with pairs of liquors. In each pair there was a test sample and a control liquor sample, both of which were identified by a code (3 digit random number). No more than four pairs of liquors were presented at each panel and no panellist received the pairs in the same order. In addition, half the panellists were presented with the test sample as the first sample of a pair while the other half received the control sample first. By these techniques the influence of order effects between samples were minimised. Per pair, each panellist completed a form indicating if the samples in the pair were identical (score 0) or not. If not identical, they quantified the magnitude of the difference as just perceptible (score 1), perceptible (score 2) or unmistakable (score 3). They then indicated which sample in the pair had flavour more similar to the control. Depending upon correct identification of the control liquor in the pair, or not, the sign of the score was assigned. If the control was correctly identified the sign of the test sample score was negative. If the test sample was indicated as being more similar to the control then the score was positive. The scores per test sample were then averaged to generate a mean sample score (MSS). An example of the form is presented as Figure 2.

*Butter from Factory Trials*

Cocoa butter produced in the factory from the commercial shipment of cocoa beans from HASCOM was evaluated monadically by a panel of screened and trained tasters experienced in cocoa butter tasting.

**FIGURE 1: CHOCOLATE ASSESSMENT FORM**

Sample No ............

**CHOCOLATE ASSESSMENT**

| **ATTRIBUTES** | | **Absent** ══════════ **Extreme** |
|---|---|---|
| 1 | Choc.Strength | |
| 2 | Sweet | |
| 3 | Acid | |
| 4 | Citrus | |
| 5 | Bitter | |
| 6 | Brown Fruit | |
| 7 | Liquorice | |
| 8 | Hammy | |
| 9 | Smokey | |
| 10 | Tobacco | |
| 11 | Mouldy | |
| 12 | Musty | |
| 13 | Baggy | |
| 14 | Nutty | |
| 15 | Earthy | |
| 16 | Bready | |
| 17 | Yeasty | |
| 18 | Sooty | |
| 19 | Metallic | |
| 20 | Astringent | |
| 21 | Rubber | |
| 22 | Aromatic | |

## FIGURE 2: LIQUOR ASSESSMENT FORM

The panel Member is presented with pairs of liquor. The samples are tasted in the order presented and the following questions are answered for each pair:

| Pair | QUESTION 1. Are the samples identical? | | QUESTION 2. If different, how large is the difference? | | | QUESTION 3. Which sample of the pair is closest to the control? | |
|---|---|---|---|---|---|---|---|
| | Identical (Score 0) | Different | Just Perceptible (Score 1) | Perceptible (Score 2) | Unmistakable (Score 3) | Sample Code | Comments |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |

**Bean Count and Cocoa Fat Yield**

A bean count was performed on the samples of beans by counting out and weighing 200 whole beans. The count was expressed as number of beans in 100g.

The theoretical fat yield of the cocoa bean samples was calculated from the % shell (S), % germ (G), nib moisture (Mn) and fat in dry nib (Fn) using the following equation:

$$\textbf{THEOR. FAT YIELD} = \frac{100 - S - G}{100} \times \frac{100 - Mn}{100} \times Fn \times 100\%$$

The shell content and germ content were determined gravimetrically by hand shelling and removing the germs from 50 beans by hand.

The nib moisture was determined gravimetrically by drying a pre-weighed sample of ground nib for 16 hours in a BS oven set at 103°C. The nib was ground for 3 sec in a household coffee grinder.

The fat in nib was determined by grinding the nibs into liquor using an end-runner mill, tempering and moulding the liquor and then extracting by soxhlet a known weight of liquor shavings overnight using hexane as a solvent. The solvent was evaporated away and the weight of fat extracted was recorded. After this pre-extraction the residual solids were ground in a pestle and mortar and extracted for 4 hours. The solvent was evaporated and the second extracted fat weight was recorded. Both extraction weights were combined and the total was expressed as a percentage of the weight of ground nib (liquor). The moisture content of the liquor was determined by the Karl Fisher method and the percentage of fat in the nib on a dry basis was calculated.

**Evaluation of Cocoa Butter Hardness**

After a standard temperature conditioning cycle, the solid fat content of cocoa butter was determined by NMR at 30°C. The NMR apparatus used was an Oxford 4000 NMR Analyser (Oxford Analytical Industries Limited, UK).

**Factory Trial**

The test beans entered the factory, were roasted, broken, winnowed and ground into liquor under standard operating practices. Cocoa butter was extracted and filtered also using the standard operating practices of the factory.

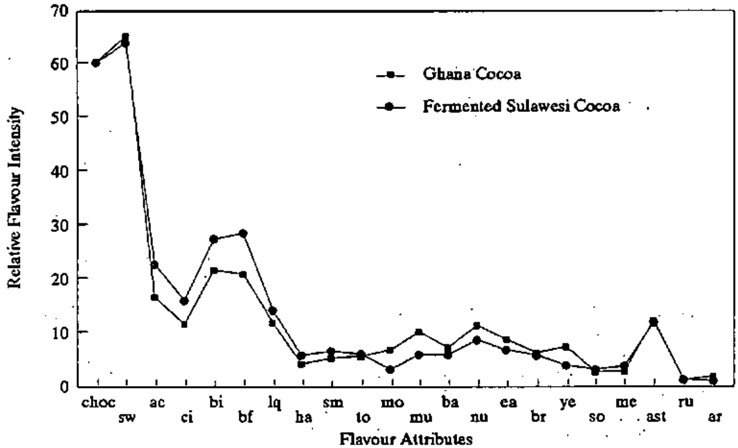
## RESULTS AND DISCUSSION

### Flavour

*The Flavour of the Small Samples of Cocoa Beans*

The average flavour profile for the samples of fermented and sun dried Sulawesi cocoa supplied to Cadbury Ltd during 1991 is shown in Figure 3 and is compared with a typical flavour profile of Ghana cocoa. There were no significant flavour differences between any of the flavour attributes considered in these two profiles. The best Sulawesi samples supplied showed no significant differences to the control chocolate made from Ghana beans. The poorest samples exhibited only a slight excess of acid, citrus, bitter and fruit flavours. The influence of these is still apparent in the averaged data for all samples shown in Figure 3.

**FIGURE 3: AVERAGE FLAVOUR PROFILES OF FERMENTED SULAWESI COCOA AND GHANA COCOA**



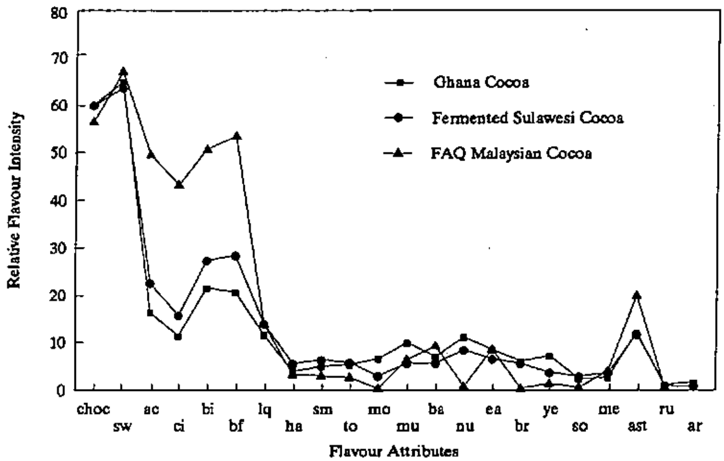

**These Average Flavour Profiles are Averages of 10 Samples from each Origin**

**Key:**

| | | | | | |
|---|---|---|---|---|---|
| choc | Choc.Strength | ha | Hammy | br | Bready |
| sw | Sweet | sm | Smokey | ye | Yeasty |
| ac | Acid | to | Tobacco | so | Sooty |
| ci | Citrus | mo | Mouldy | me | Metallic |
| bi | Bitter | mu | Musty | ast | Astringent |
| bf | Brown Fruit | ba | Baggy | ru | Rubber |
| lq | Liquorice | nu | Nutty | ar | Aromatic |
| | | ea | Earthy | | |

The data in Figure 4 shows a sample of fair to average quality (FAQ) Malaysian cocoa beans. Although this sample had none of the objectionable hammy and smokey off-flavours often found in FAQ beans from this source, the level of acid, citrus, brown fruit and astringency in this sample and the lack of chocolate character are typical of FAQ Malaysian and Indonesian cocoa. Relative to this FAQ cocoa, the similarity of the fermented and sun dried Sulawesi cocoa to Ghana cocoa rather than to FAQ cocoa from S.E.Asia is obvious.

**FIGURE 4: AVERAGE FLAVOUR PROFILES OF FERMENTED SULAWESI COCOA AND GHANA COCOA COMPARED WITH FAQ MALAYSIAN COCOA**




**The Average Flavour Profiles are Averages of 10 Samples from each Origin**

**Key:**

| | | | | | |
|---|---|---|---|---|---|
| choc | Choc.Strength | ha | Hammy | br | Bready |
| sw | Sweet | sm | Smokey | ye | Yeasty |
| ac | Acid | to | Tobacco | so | Sooty |
| ci | Citrus | mo | Mouldy | me | Metallic |
| bi | Bitter | mu | Musty | ast | Astringent |
| bf | Brown Fruit | ba | Baggy | ru | Rubber |
| lq | Liquorice | nu | Nutty | ar | Aromatic |
| | | ea | Earthy | | |

*The Flavour of Liquor from the 30% Bean Sample and the Factory Trial*

Liquor prepared from the 30% bean sample taken from the commercial shipment and liquor produced while the beans were being processed through the factory, were compared directly with liquors produced from Ghana beans. These results are shown in Table 2.

**TABLE 2: EVALUATION OF LIQUOR FROM FERMENTED SULAWESI COCOA BEANS IN COMPARISON TO LIQUOR FROM GHANA BEANS**

| Liquor Samples from Fermented Sulawesi Beans and Blends | Mean Sample Score (MSS) |
|---|---|
| Liquor from 30% bean sample | -0.5 |
| Liquor from factory trial blended at 50% in Ghana liquor | -0.3 |
| Liquor from factory trial blended at 75% in Ghana liquor | -0.6 |
| Liquor from factory trial | -1.5 Acid; Raw; Green |

A Mean Sample Score (MSS) of +/-0.5 is the typical uncertainty in this type of tasting and indicates that the sample and the control liquor were not significantly different. Routine tasting of acceptable commercial parcels of Ghana cocoa by this method produces MSS in the range +0.5 to -0.9. The liquor produced from the 30% sample taken from the 100 tonne parcel of fermented Sulawesi beans was not detected by expert tasters as being different from acceptable Ghana cocoa. However a significant difference was detected between the factory liquor produced from 100% fermented Sulawesi beans and the equivalent Ghana liquor. The comments noted for factory produced liquor (acid, raw and green) are consistent with the residual excess acid and associated flavours seen in the averaged flavour profile for the 10 small samples (Figure 3). These comments may indicate that the level of fermentation within the parcel of 100 tonnes was low in comparison to that of commercial Ghana cocoa. The fermented Sulawesi beans were considered acceptable by Cadbury Ltd for use in a 75% liquor blend with Ghana beans. This compares with FAQ Indonesian and Malaysian beans which are normally not usable by Cadbury Ltd for chocolate manufacturing at above 10% and also with cocoa from better Indonesian and Malaysian estates which are limited to 25% use at best. These initial tasting results are therefore very encouraging.

*The Flavour of (Natural) Cocoa Butter Produced during the Factory Trial*

A natural cocoa butter produced during the factory trial from the test beans was assessed by a tasting panel experienced in evaluating commercial cocoa butters. The evaluation indicated that the cocoa butter flavour was typical of butters derived from Ghana beans processed in the same production line. It was free from objectionable off-flavours and was suitable for use in chocolate making without deodorisation.

**Fat Yield**

The analytical data on 10 laboratory scale samples of fermented and sun dried Sulawesi cocoa received over a 10 month period is shown in Table 3. The average size of the Sulawesi beans is reasonable although they were smaller (higher bean count/100g) than the West African cocoa. The shell content is high compared with West African beans and the fat in dry nib is very low. These last two factors affect the fat yield relative to a tonne of West African cocoa beans. In these terms 1 tonne of Sulawesi beans would provide about 35 kg less fat than 1 tonne of West African beans. Therefore to produce the same quantity of fat it would be necessary to grind about 9% more Sulawesi beans than West African beans and ultimately, this will be directly reflected in the price that a user would be prepared to pay for the beans. Indeed, certain end users with capacity constraints in their factories might not be able to accept the consequential reduction in output from using Sulawesi beans.

**TABLE 3: FAT YIELD FROM FERMENTED AND SUN DRIED SULAWESI COCOA BEANS RELATIVE TO WEST AFRICAN COCOA BEANS**

| Analytical Measures | Fermented and Sun Dried Sulawesi Cocoa | West African Cocoa (5 year average) |
|---|---|---|
| Bean Count (No. Beans/100g) | 104.2 (96 to 110) | 93.7 |
| Whole Bean Moisture (%) | 6.2 | 6.0 |
| Shell Content (%) | 14.6 (13.4 to 16.2) | 11.8 |
| Germ Content (%) | 0.9 | 0.9 |
| Nib Moisture (%) | 5.3 (52.1 to 54.5) | 5.1 |
| Fat in Nib (% on dry basis) | 53.1 | 57.3 |
| **Theoretical Fat Yield (%) (i)** | **42.49** | **47.47** |

(i) Calculated using the formula presented earlier in this article.

It is likely that the low fat yield from Sulawesi cocoa is due to the planting material which has been used, a systematic breeding programme for fat yield could gradually change this situation over time.

**Fat Hardness**

The solid fat content of the cocoa butter extracted from the Sulawesi beans and similar data for cocoa butters from other beans are shown in Table 4. Clearly cocoa butter from Sulawesi beans is considered among the harder cocoa butters available. Hard cocoa butter is valued by certain end users, grinders and chocolate makers alike. Its value is that it allows them to counter the softening introduced into their cocoa butter blends or product recipe through use of cocoas (which are perhaps necessary for flavour or colour reasons), but which contain very soft cocoa butter or to compensate for use of milk fat which itself is very soft.

**TABLE 4: HARDNESS OF COCOA BUTTER FROM FERMENTED AND SUN DRIED SULAWESI COCOA BEANS RELATIVE TO COCOA BUTTER FROM OTHER BEAN TYPES**

| Cocoa Bean Origin | Percentage Solid Fat @ 30°C by NMR |
|---|---|
| Sulawesi (Hascom) | 64.1 |
| Malaysia | 60 to 65 |
| West Africa | 50 to 59 |
| Brazil | 35 to 50 |
| **Milk Fat (from cow)** | **Less than 1%** |

## CONCLUSIONS

The flavour of this parcel of fermented and sun dried Sulawesi smallholder cocoa and the products produced from them in the factory of Cadbury Ltd was very encouraging and showed the potential to be as good as the best of West African cocoas. Although, the 100 tonnes parcel of cocoa received was not identical to Ghana cocoa flavour it came very close to it. The beans were certainly fermented, although possible slightly less thoroughly than normally seen in West African cocoas.

In value terms, fermented Sulawesi cocoa has a strength and a weakness. The strength is difficult to quantify in price terms, but is shown by the very hard cocoa butter it contains which is sought by some, though not all end users. Conversely, the very low fat yield per tonne is a major weakness which can be readily quantified relative to other cocoas.

It is suggested that there maybe a future demand for fermented Sulawesi cocoa amongst chocolate manufacturers and intermediate cocoa processors alike. In the light of this, it may well be worthwhile encouraging growers to ferment their cocoa on the farm or in central fermentaries and also to encourage exporters to keep fermented cocoa separate from cocoa which is unfermented. At the moment both types of cocoa are present in the same sack.

## REFERENCES

*Duncan,R.J.E.* (1986) A Survey of Ghanaian Cocoa Farmers Harvesting, Fermentation and Drying Practices and their Implications for Malaysian Practices. Proceedings of International Cocoa Conference. Cocoa and Coconuts: Progress and Outlook. Incorp. Soc. Planter, Kuala Lumpur, 1986, pp.506-516.

*Wood,G.A.R. and Lass,R.A.* (1985) Cocoa 4th Edition. Tropical Agricultural Series, Longman Group Limited, London.

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# EXPERIMENTS TO DETERMINE INFLUENCE OF PRIMARY PROCESSING PARAMETERS AND PLANTING MATERIAL ON THE FLAVOUR OF COCOA BEANS IN MALAYSIA

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## INTRODUCTION

The experiments reported here began in April 1989 at about the time of the publication of the Sime/Cadbury process (Duncan et al., 1989). In parallel, experiments were also underway to improve cocoa flavour by pre-conditioning wet beans prior to fermentation (Said et al., 1990). Earlier, Lewis and Lee (1986) had demonstrated improvements in flavour resulting from a combination of post-harvest, fermentation and drying treatments. Not all of the processing treatments that were being proposed were attractive to Malaysian producers for practical reasons. Pod storage prior to extraction of wet beans increases labour costs by at least doubling the amount of handling and transport of pods after harvesting and the risk of spread of the cocoa pod borer (Day, 1985). Slow drying presents capacity problems, particularly on large estates, during crop peaks. At current cocoa prices the additional costs associated with pod storage and slow drying are unacceptable to most Malaysian producers, as the premium offered for cocoas with improved flavour is not yet sufficient to compensate adequately for the additional effort.

This study was undertaken to identify the effects of the different processing treatments relative to standard practices with a view to understanding how, and why, they affect flavour. Armed with that new knowledge and understanding, it should be possible to develop more practical and cost effective ways of achieving the same, or even a better, end result.

There were four distinct stages of the present work. The first series of trials investigated the relative effects of pod ripeness at harvest, pod storage prior to extraction of wet beans and fermentation and drying conditions. A significant effect of 4 days pod storage in improving cocoa flavour and a directional effect of slow drying in reducing acidity were identified.

A second series of trials used heap and box fermentation to examine the effects of increased times of pod storage and to compare the relative effects of pod storage and pulp pre-conditioning. Better flavour was obtained by increasing the pod storage time to 9 days. The flavour improvements that resulted from pre-conditioning wet beans by a period of sun-drying prior to fermentation were marginal compared to the effects of 4 and 9 days pod storage.

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The third series of trials examined the effects of 3, 6 and 9 days pod storage, each with three different post-fermentation drying treatments. These trials were repeated three times over a period of 15 months and are the main trials on which the present results are based. The best flavour quality was obtained from 9 days pod storage followed by sun-drying.

A final series of trials examined the effects on flavour of conditioning beans in a current of air to achieve the same conditions of pulp as that achieved by 9 days pod storage. Although the same conditions of pulp and the same patterns of subsequent fermentation were arrived at in both treatments, there were no corresponding improvements in flavour.

## METHODS

### Harvesting, Fermentation and Drying Treatments

In the first trials harvested pods were sorted into sets of fully ripe pods (>75% yellow) and under-ripe pods (<25% yellow). Subsequently, normal conditions of ripeness at harvest were used. Pods were stored in the fields in heaps of about 300 pods, close to main roadways where they could be guarded.

The main trials were carried out at Sungei Bernam Estate during off-peak crop periods when surplus fermentation and drying capacity were available. The traditional cascade fermentary at the factory was used. Charges of 2.5 tonnes of wet beans were fermented in boxes at 40 cm bean depth. The surfaces of the fermentations were covered with gunny sacks. About 350 kg wet beans were also fermented in heaps (as is normally practised in West Africa by smallholders) on a base of banana leaves. The heap fermentations were covered with banana leaves and were left for 5 days with a single turn after the second day.

Wet beans were conditioned by allowing them to stand overnight in the fields in the perforated bins used to transport wet beans from the fields to the fermentary. After standing overnight, the wet beans were spread in the sun for 4 hours prior to fermentation. In trials carried out at the Research Centre at Jenderata Estate of United Plantations Berhad, 1000 kg of wet beans were conditioned in a current of air prior to fermentation. The pre-conditioning treatment was at 4 cm bean depth on a stack of slatted trays. The conditioned beans were fermented in boxes at 25 cm bean depth.

Beans were force dried in circular-bin, flat-bed dryers. Air to the dryers was heated indirectly from a hot water system with a solid fuel furnace to the right temperature. Beans were sun-dried on woven bamboo mats on raised platforms and covered at night or when it rained.

### Analytical Procedures

Random samples of 30 pods were taken from each harvest before and after storage for analyses of pulp and beans. This sample size was sufficient to reveal differences in pulp volume and fresh weight of wet beans corresponding to the different pod storage times. The variation in beans between individual pods and between harvests, which were spread over several seasons, negated attempts to reveal smaller differences. For example, from the error variance between samples, it is estimated that samples of 900 pods (ie. $30^2$) would have been required to reveal statistically significant differences in the sugar content of pulp and moisture of cotyledons. It was not possible with the available labour to carry out that amount of sample preparation and the pulps and cotyledons would probably have changed while the materials were being prepared for the analyses. Because of the amount of work involved and the difficulty in maintaining the pods in appropriate condition, the use of larger sample sizes was therefore impracticable.

Volumes of beans before and after manual depulping were estimated by water displacement. Lactic acid contents of whole beans, nibs and shells were estimated colorimetrically as described by Barker and Summerson (1941).

Coded samples of dried beans were sent to the UK for taste testing where they were tasted as cocoa liquors by an individual assessor according to the procedures described in Clapperton et al. (1991).

## RESULTS

### First Series of Trials

The first series of trials examined the effects of two conditions of each of the following four factors:

| Factor | Condition | |
|---|---|---|
| Ripeness at harvest | (i) | Pods fully ripe at harvest |
| | (ii) | Under-ripe pods |
| Pod storage | (iii) | None |
| | (iv) | 4 days |
| Fermentation regime | (v) | Shallow box fermentation (40 cm bean depth) for 5 days with one turn after the second day |
| | (vi) | Shallow box fermentation for 7 days with three turns after the second, fourth and sixth day |
| Drying regime | (vii) | Slow drying at up to 40°C maximum |
| | (viii) | Fast drying at 60°C |

A full factorial experimental test design gave a total of 16 separate fermentation and drying treatments. The results in Table 1 are the averages of 4 scores for each factor/condition combination. The 'p-value' statistic indicates the likelihood of the result arising by chance (where the higher value indicates a chance occurrence). Values of p deducted from 100 give the confidence levels usually denoted by *=95%, **=99% and ***=99.9% and used later in this paper to indicate the statistical significant of differences relating to effects of pod storage and conditions of drying. Values of p greater than 5%, or less than 95% confidence, indicate that differences in scores or estimates are not statistically significant.

**TABLE 1: RESULTS OF THE TRIALS ON HARVESTING, FERMENTATION AND DRYING CONDITIONS**

| | | Cocoa Flavour | Acid Taste | Sour Taste | Lactic Acid (mg/100g) |
|---|---|---|---|---|---|
| **Ripeness at Harvest** | | | | | |
| (i) | Fully ripe | 5.9 | 8.1 | 5.1 | 656 |
| (ii) | Under ripe | 5.8 | 8.4 | 5.7 | 685 |
| | p-value % | (68) | (67) | (39) | (80) |
| **Pod Storage** | | | | | |
| (iii) | None | 5.4 | 9.1 | 6.4 | 794 |
| (iv) | 4 days | 6.3 | 7.4 | 4.4 | 548 |
| | p-value % | (1.1) | (0.1) | (0.03) | (1.8) |
| | | * | ** | *** | * |
| **Fermentation Regime** | | | | | |
| (v) | 5 days, 1 turn | 5.7 | 8.1 | 5.7 | 649 |
| (vi) | 7 days, 3 turns | 6.0 | 8.4 | 5.1 | 693 |
| | p-value % | (60) | (74) | (43) | (70) |
| **Drying Regime** | | | | | |
| (vii) | Slow drying | 6.0 | 8.1 | 5.0 | 568 |
| (viii) | Fast Drying | 5.7 | 8.4 | 5.8 | 773 |
| | p-value % | (41) | (62) | (29) | (5.8) |

The figures for lactic acid are from analyses of coned and quartered samples of the dried beans. The flavour characteristics were scored for intensity on a 15 cm line scale. Higher scores denote stronger intensities. There were no significant flavour effects on the conditions of ripeness at harvest or of the different fermentation regimes. It is appropriate therefore to follow the usual practice of Malaysian estates, namely that of harvesting pods that have just turned yellow rather than attempting to select fully ripe pods on the basis of colour. There is no benefit in flavour from the longer fermentation time and extra turns.

**Effects of Pod Storage and Pulp Pre-Conditioning (Second Series of Trials)**

The best flavour from the first series of experiments was obtained from fully ripe pods, 4 days pod storage, 5 days fermentation with a single turn and slow drying ie. the combination of treatments (i), (iv), (v) and (vii). Although this was a distinct improvement on the flavour of the contrasting combination (ie. (ii), (iii), (vi) and (viii)) which corresponded to the standard production conditions at Sungei Bernam Estate (United Plantations Berhad) during low crop periods, it was still far short of the target flavour, which was that normally produced by West African smallholders. Effects of longer pod storage times were investigated in a series of trials prior to the next main round of experiments which were to be replicated to confirm the effects of the processing treatments. It was important therefore to identify appropriate processing treatments at the outset. Fermentation heaps of 350 kg were used to assess the effect of 9 days pod storage. The beans from these fermentation heaps were sun dried. The effect of conditioning the pulp by spreading wet beans in the sun prior to fermentation was also investigated. 2.5 tonnes of conditioned beans were fermented in boxes for 5 days with a single turn after the second day as in the first experiment. The fermented beans were dried slowly in a current of air at ambient temperature.

The idea of conditioning the pulp prior to fermentation is based on the understanding that cocoa flavour development depends on acidification of the beans which in turn depends on the condition of the pulp affecting the pattern of development of micro-organisms and the course of fermentation (Biehl et al., 1985). Pulp pre-conditioning treatments by bean spreading or by air blasting prior to fermentation were designed to bring about the same changes in pulp characteristics that are achieved by pod storage but in a much shorter period of time (Said et al., 1990).

The desired reductions in pulp volume and fresh weight of beans were achieved by allowing the wet beans to stand in the fields overnight and then spreading them in the sun prior to fermentation. This pulp pre-conditioning did have the desired effect on the patterns of fermentation, giving the same early and rapid rise in temperature as occurred in the fermentations of beans from stored pods. The flavours of the final cocoa beans however, were poorer than those from 4 and 9 days pod storage. The results are shown in Table 2.

**TABLE 2: EFFECTS OF POD STORAGE AND BEAN SPREADING ON FLAVOUR QUALITY**

| | | Cocoa Flavour | Acid Taste | Sour Taste |
|---|---|---|---|---|
| 4 days pod storage | Combination (i), (iv), (v), (vii) | 7.4 | 6.0 | 3.7 |
| No pod storage | Contrasting cocoa (ii), (iii), (vi), (viii) from 1st trial | 5.6 | 9.3 | 6.6 |
| Spread beans | Normal pod ripeness at harvest | 5.8 | 7.4 | 3.9 |
| Spread beans | Under ripe at harvest | 6.2 | 7.1 | 3.3 |
| 9 days pod storage | Fermentation heap | 9.6 | 3.7 | 1.7 |
| West African | Commercial samples with acceptable flavour quality | 10.5<br>9.0<br>9.1 | 2.2<br>1.8<br>2.1 | 0<br>0.3<br>0 |

**Effects of Drying Treatments (Third Series of Trials)**

The processing treatments tested in this experiment followed from the results of the first two experiments. Effects of 3, 6 and 9 days pod storage, each with three post-fermentation drying treatments, were tested. Beans were dried at ambient temperature or alternatively at 40°C initially to a moisture content of 20% and then at 60°C to a final moisture content of about 7.5%. Portions of the beans (each of 200 kg) scheduled for initial drying at ambient temperature were sun dried throughout. Normal conditions of pod ripeness at harvest were used. Wet beans were fermented in shallow boxes for 5 days with a single turn after the second day. The fermentations were carried out during low crop periods from November 1989 to January 1991 and were repeated three times. The results of the flavour analyses in Tables 3 and 4 are the average of 6 'blind' tests of each cocoa liquor.

The effects of the drying conditions on flavour are shown in Table 3 together with the average times taken to dry the cocoas. The differences in acid/sour taste are significant at 99.9% confidence (***). The differences in cocoa flavour and astringency are significant at 95%

confidence (*) but are probably more due to the marked difference in acidity and sourness rather than drying conditions having a direct effect on cocoa flavour development.

**TABLE 3: EFFECTS OF THE DRYING TREATMENTS**

| Drying Time (hours) | 40°C/60°C (72) | Ambient/60°C (84) | Sun Dried (184) | Statistical Significance |
|---|---|---|---|---|
| Cocoa flavour | 6.2 | 6.0 | 6.9 | * |
| Acid taste | 7.2 | 6.9 | 5.8 | *** |
| Astringent | 6.7 | 6.5 | 6.0 | * |
| Fragrant | 1.0 | 0.9 | 1.3 | |
| Sour taste | 5.1 | 4.8 | 3.1 | *** |

The effects of the drying conditions in reducing acid/sour taste are supported by the results of the analysis of the residual levels of lactic acid in the dried beans. The beans dried at ambient/60°C and by sun drying were from the same fermentations and therefore contained the same concentrations of lactic acid before drying. Whole beans dried at ambient/60°C contained 651 mg lactic acid/100g whereas the sun dried beans contained 518 mg/100g. Estimates of the concentrations of lactic acid present in shells and nibs from 9 samples of beans representing all three drying treatments showed the shells to contain much higher concentrations than the nibs:

| | | | |
|---|---|---|---|
| Shells | - Average | 1636 mg/100g | (range 831 - 2417) |
| Nib | - Average | 429 mg/100g | (range 300 - 518) |

The shells contained 16% moisture compared with 6% in the nibs. During drying, organic acids, which are formed during fermentation and are absorbed into the beans, migrate from the nibs to the shells where they are lost either by evaporation or by decomposition. Sun drying is more effective than artificial drying in achieving this effect mainly because the beans remain moist longer thereby allowing sufficient time for migration and loss of the acids to occur.

**Effects of Pod Storage (Third Series of Trials)**

Whereas the drying conditions affected mainly acidity and sourness, pod storage had a greater effect on a larger number of flavour characteristics, particularly the development of cocoa and chocolate flavours (Table 4). The term fragrant in that Table refers to the aromatic smell and flavour of well developed cocoa flavour and particularly of good quality West African cocoas.

**TABLE 4: EFFECTS OF POD STORAGE ON COCOA FLAVOUR QUALITY**

| Pod Storage Time | 3 days | 6 days | 9 days | Significance |
|---|---|---|---|---|
| Cocoa flavour | 5.2 | 5.6 | 8.3 | *** |
| Acid taste | 7.4 | 7.4 | 5.1 | *** |
| Astringent | 6.9 | 7.0 | 5.5 | *** |
| Chocolate | 0.1 | 0.5 | 1.5 | *** |
| Fragrant | 0.1 | 0.4 | 2.6 | *** |
| Sour | 5.2 | 5.1 | 2.8 | *** |

The reductions in pulp volume and fresh weight of beans corresponding to the pod storage treatments are shown in Figures 1 and 2 respectively. The average values per bean are shown with the error bars representing plus and minus the standard errors of the estimates.

The major changes in pulp occurred between 3 and 6 days. There were no further changes in pulp between 6 and 9 days corresponding to the marked improvements in flavour (as shown in Table 4).

This indicates that the flavour improvements resulting from pod storage are unlikely to be achieved by modification of the pulp alone, either prior to, or during, fermentation. Further evidence of this was provided by the trials in which wet beans were conditioned in a current of air to achieve the same conditions of pulp and subsequent fermentation patterns corresponding to the effects of 9 days pod storage observed in the third experiment. Although the target conditions of pulp and fermentation patterns were achieved consistently and reproducibly, the flavours of the fermented and dried cocoas were distinctly disappointing and showed no flavour improvement whatsoever.

Attention must therefore be turned to possible changes occurring in the cotyledons particularly during the longer periods of pod storage. It is possible these longer pod storage times are effective because they allow more time for the critical changes in the cotyledons to occur. Support for this hypothesis is gathering from studies at BAL Plantations on the effects of cocoa genotypes on flavour (Clapperton et al., 1991). The genotypes, UIT-1 and Nanay-33, are shown to differ in sourness and astringency, in the concentrations of polyphenols present in the cotyledons and in the pod storage times they require to develop acceptable flavour. UIT-1 is characterised an excessively bitter and astringent taste which is ameliorated only after 10 or more days pod storage.

**FIGURE 1: REDUCTION IN PULP VOLUME DURING POD STORAGE**

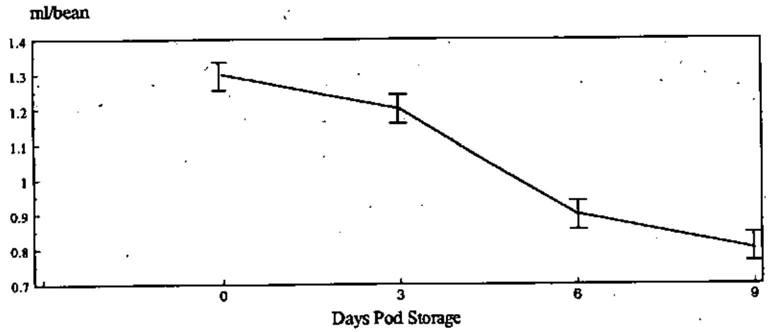
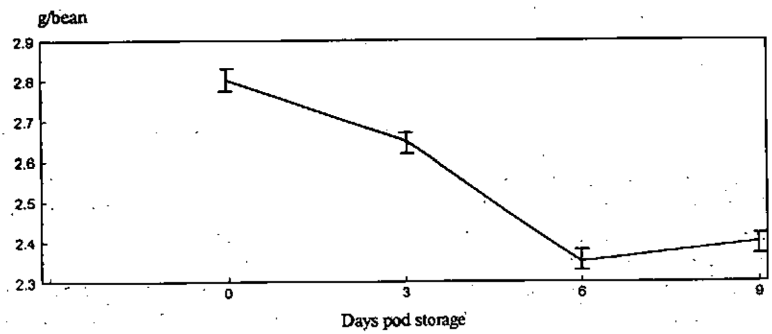



**FIGURE 2: REDUCTION IN FRESH WEIGHT OF BEANS DURING POD STORAGE**




### Influence of Planting Material

The contribution of the planting materials to flavour at United Plantations Berhad was shown in cocoas from two parallel fermentations in which beans from rough, warty, pods similar in appearance to UIT-1, and beans from smooth, rounded pods were compared directly. Freshly harvested pods of both groups were broken on the same day. Woven rattan baskets were used to control the size and shape of the two 35 kg fermentations. The beans were fermented for 5 days with a single turn after the second day. After fermentation, the beans were all sun dried. The results of three blind taste tests of the cocoa liquors show that the flavours were clearly distinguishable, particularly the bitter, astringent and sour tastes which have been noted to be characteristic of the flavour of UIT-1 (Table 5). The widespread use of UIT-1 in cocoa seed production in Malaysia may be part of the reason why long pod storage times seem to be required to develop acceptable flavour from Malaysian cocoas.

**TABLE 5: EFFECT OF PLANTING MATERIAL ON COCOA FLAVOUR QUALITY**

| | Test | Cocoa Flavour | Bitter | Acid | Astringent | Sour |
|---|---|---|---|---|---|---|
| Rough, warty pods (i) | 1 | 4.5 | 7.5 | 5.3 | 9.0 | 9.0 |
| | 2 | 3.8 | 9.0 | 4.5 | 10.5 | 10.5 |
| | 3 | 3.0 | 7.5 | 4.5 | 10.5 | 10.5 |
| Smooth rounded pods | 1 | 7.5 | 3.0 | 3.0 | 3.0 | 3.0 |
| | 2 | 6.8 | 3.8 | 6.0 | 4.5 | 4.5 |
| | 3 | 6.0 | 4.5 | 4.5 | 3.0 | 4.5 |

(i) These pods looked very similar to UIT-1 pods.

## CONCLUSION

The stated objectives of this study were to develop a better understanding of the origins of cocoa flavour development and to discover cost-effective ways of improving the quality of Malaysian cocoa. Pod storage is shown to be the single most important factor affecting cocoa flavour quality and has not been effectively substituted by simple modification of the pulp prior to fermentation. Cost-effective flavour improvements are therefore more complex, requiring further investigation of effects of processing and/or the development of new planting materials with improved flavour potential. Shorter term, it may be appropriate to Malaysia, and especially the larger estates, to pay some attention to cocoa butter production. That would effectively buy time for development of the new planting materials and processing treatments to enhance the flavour.

## REFERENCES

*Barker,S.B. and Summerson,W.M.* (1941) The Colorimetric Determination of Lactic Acid in Biological Material. J. Biol. Chem., **138**, pp.535-554.

*Biehl,B., Brunner,E., Passern,D., Quesnel,V.C. and Adomako,D.* (1985) Acidification, Proteolysis and Flavour Potential in Fermenting Cocoa Beans. J. Sci. Food Agric., **36**, pp.583-598.

*Clapperton,J.F., Yow,S.T.K., Chan,J., Lim,D.H.K., Lockwood,G., Romanczyk,L. and Hammerstone,J.F.* (1991) The Effect of Cocoa Genotypes on Flavour. Proceedings of the International Cocoa Conference, Challenges in the 1990s, Kuala Lumpur. Malaysian Cocoa Board, Kota Kinabalu, pp.468-478.

*Day,R.K.* (1985) Control of the Cocoa Pod Borer, Conopomorpha cramerella, PhD Thesis. The University of London, UK.

*Duncan,R.J.E., Godfrey,G., Yap,T.N., Pettipher,G.L. and Tharumarajah,T.* (1989) Improvement of Malaysian Cocoa Bean Flavour by Modification of Harvesting, Fermentation and Drying Method - the Sime/Cadbury Process. The Planter, Kuala Lumpur, **65**, pp.157-173.

*Lewis,J.F. and Lee,M.T.* (1986) The Effects of Harvesting, Fermentation and Drying on Cocoa Flavour Quality. The Planter, Kuala Lumpur, **62**, pp.134-140.

*Said,M.B., Jayawardena,M.P.G.S., Samarkoddy,R. and Perera,W.T.* (1990) Pre-conditioning of Fresh Cocoa Beans Prior to Fermentation to Improve Quality: A Commercial Approach. The Planter, Kuala Lumpur, 66, pp.332-345.

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# EFFECTS OF PLANTING MATERIALS ON FLAVOUR

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## INTRODUCTION

When the effects of primary processing treatments on cocoa flavour were known, the obvious next step was to use a standard processing regime to test the effects of different planting materials. BAL Plantations Sdn Berhad in Malaysia provided the ideal venue, both in terms of available germplasm and management skills to run a project involving extensive and replicated field trials, as well the preparation and collation of test samples for instrumental and sensory analyses. There were sufficient trees there of many individual genotypes to provide 50 kg, and in some cases, 500 kg of wet beans from a single harvest for monoclonal fermentation. After trials on both scales of preparation had revealed consistent and reproducible differences in flavour among primary genotypes (Clapperton et al., 1991, 1994), a project, funded by the Biscuit, Cake, Chocolate and Confectionery Alliance, was undertaken to assess the rest of the planting materials at BAL. This paper lists the planting materials which have been examined to date with a commentary on the major effects on flavour that have been observed. Details of the experimental protocols for sample preparation and taste testing are appended. The entire primary taste testing was carried out by a single assessor and involved repeated blind tests of cocoa liquors according to experimental test designs. More than 4,000 cocoa liquors have been tasted in the course of the project and the use of a single assessor was the only way of keeping the sensory evaluation in phase with the production of test samples. Key results have been confirmed by taste panels from BAL trained during the course of the project and also by entirely independent panels representing cocoa and chocolate manufacturers from Europe and USA. Effects of planting materials on flavour identified initially by the single assessor have been confirmed also by instrumental analyses.

## RESULTS AND DISCUSSION

Planting materials which have been tested since the start of the project in 1990 are listed in Table 1. Flavour scores, which from left to right refer to cocoa flavour intensity, astringency, fruity flavour and viscous/thick mouthfeel, are the averages of at least three

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replicate preparations of each planting material, and are entered for materials which showed consistent flavour development between replicate preparations. Otherwise, the flavours are indicated as "Variable". Intensities of flavour characteristics were scored on a 10 cm line scale. Higher scores denote stronger intensities.

**TABLE 1: FLAVOUR PROFILES OF PLANTING MATERIALS**

| Planting Material | Flavour Scores | Replicates and Details | Planting Material | Flavour Scores | Replicates and Details |
|---|---|---|---|---|---|
| AMAZ2-1 | 3.4,3.5,0,6.3 | 3 | IMC14 | 6.9,2.0,1.2,6.8 | 3* |
| AMAZ15-15 | 5.4,3.4,0,7.6,0 | 10e | IMC23 | Variable | 4 |
| AML | 6.3,2.7,0.8,7.2 | 22a,e | IMC47 | 4.8,4.2,0.8,6.4 | 3# |
| BAL209 (i) | 3.1,4.9,0.9,4.9 | 157a,c,d | IMC53 | 6.3,2.8,0,6.6 | 4 |
| BAL244 (ii) | 5.6,2.2,3.9,7.2 | 3* | IMC67 | 3.1,4.5,0.2,5.1 | 30a,b,e |
| BR25 (iii) | 2.1,4.5,0,2.4 | 3 | IMC85 | 5.7,3.3,10,7.2 | 3 |
| CC10 | 2.1,6.4,0.2,5.8 | 12d | IMC105 | 6.4,2.9,2.7,7.2 | 3* |
| CC11 | 3.0,6.2,0.8,5.3 | 3* | K13 | 3.2,5.4,0,4.9 | 3# |
| CC38 | 6.4,2.9,1.9,7.1 | 3# | K20 | 2.8,5.3,0.9,5.0 | 3* |
| CC41 | 6.8,1.9,4.9,8.6 | 3# | K21 | 2.6,6.5,0.7,4.8 | 6# |
| CC54 | Variable | 5# | K82 | 2.3,6.5,0.2,4.6 | 12d |
| EET283 | 5.2,3.8,0.9,6.9 | 3# | KA2-101 | 5.0,2.6,0.7,6.3 | 3* |
| EET308 | 6.3,2.5,2.1,6.8 | 3* | KA2-106 | 6.6,2.8,2.9,7.3 | 4# |
| EET376 | 3.0,6.2,0,5.6 | 3# | KA5-201 | Variable | 12d |
| *EET376* | 7.1,2.9,2.4,7.7 | 3# | K6-101 | 2.6,5.5,0.2,4.1 | 3# |
| EET399 | 2.9,4.5,1.0,4. | 3* | K24-106 | 3.4,4.8,0.3,4.2 | 2# |
| GA57 | 3.6,5.5,0,6.2 | 3# | LCT-EEN37A | 3.6,4.4,3.8,4.3 | 2# |
| ICS1 | 5.9,2.7,3.4,7.5 | 3* | LCT-EEN73E | 6.1,3.3,2.0,7.2 | 3# |
| ICS6 | 4.2,4.1,0.6,5.8 | 3* | LCT-EEN258E | 6.0,2.9,1.5,6.7 | 2# |
| ICS8 | 3.5,5.2,0,5.8 | 3# | MATINA1-9 | 6.3,2.8,2.0,7.2 | 3# |
| ICS16 | 6.8,2.4,0.4,7.4 | 3* | MO81 | 6.1,2.8,2.1,6.7 | 3* |
| ICS46 | 5.1,4.3,0.4,5.6 | 3# | MOQ417 | 1.9,7.8,0,5.1 | 3# |
| ICS60 | 2.2,7.0,0.2,4.1 | 3# | NA26 | 3.8,5.3,0.2,4.6 | 3# |
| ICS84 | 2.7,6.5,0.2,4.9 | 3# | NA27 | 6.5,2.9,0.7,6.6 | 3# |
| ICS95 | Variable | 14d | NA31 | 6.5,2.3,3.8,7.0 | 3* |
| ICS98 | 1.7,6.9,0,4.1 | 3# | NA32 | 3.7,4.1,0,6.1 | 3 |
| ICS100 | 4.8,3.3,0.5,6.9 | 3# | NA33 | 6.9,2.4,2.6,7.6 | 56a,c,d,e |

(i) BAL209 = *PA35*xNA32;
(ii) BAL244 = (UITxN32)xIMC67;
(iii) BR25 = Malaysian selections of unknown provenance probably Trinitario.
**Note:** The identity of planting materials in *italic* print is uncertain.

**TABLE 1: FLAVOUR PROFILES OF PLANTING MATERIALS CONTINUED**

| Planting Material | Flavour Scores | Replicates and Details | Planting Material | Flavour Scores | Replicates and Details |
|---|---|---|---|---|---|
| NA34 | 4.8,4.0,0,7.2 | 3 | PA156 | 3.8,3.6,0,6.9 | 3 |
| NA70 | 5.5,3.2,1.1,6.2 | 3# | PA300 | 4.7,4.0,0,4.8 | 4 |
| NA77 | 3.4,4.9,0.5,4.7 | 3# | *PA35* | 3.8,4.6,2.5,6.9 | 3 |
| NA101 | 4.4,4.3,0.6,5.6 | 3# | PBC123 (i) | 6.2,2.3,1.7,6.9 | 21a,d |
| NA110 | 6.4,2.6,2.3,7.0 | 3# | 10P | 3.5,4.6,0,5.6 | 3 |
| NA121 | 3.7,5.0,0.1,5.3 | 3# | RED AML1-21 | 2.5,6.5,0.2,4.8 | 3# |
| NA141 | 4.0,4.6,1.3,5.3 | 4# | SCA6 | 6.9,2.5,4.3,8.2 | 3 |
| NA149 | 5.5,3.1,1.5,6.6 | 3# | SCA9 | 4.4,3.7,1.3,7.3 | 29e |
| NA162 | 4.5,4.2,0.3,5.6 | 3# | SCA12 | 6.6,2.5,5.3,8.3 | 28d,e |
| NA171 | 6.9,2.3,2.4,5.7 | 3# | SCR5 | Variable | 3# |
| NA180 | 4.1,5.3,3.1,5.7 | 3# | *SIAL93* | 7.0,2.0,1.2,7.1 | 3* |
| NA214 | 5.8,3.0,0.2,5.7 | 3# | SPA9 | 6.8,2.5,2.3,7.9 | 3 |
| NA226 | 3.7,5.1,0.5,5.1 | 3# | SPA10 | 6.6,2.8,1.7,7.3 | 3* |
| NA227 | 6.7,2.2,1.0,6.9 | 2# | TAP1-2 | Variable | 6# |
| NA235 | 7.1,2.4,3.4,7.7 | 3# | UF11 | 1.3,7.5,0,3.6 | 3* |
| NA250 | 5.8,3.1,0.3,6.2 | 3# | UF29 | 3.7,4.4,0,6.5 | 2# |
| NA258 | 7.6,1.8,2.5,7.9 | 3# | UF168 | 2.8,4.0.3,4.6 | 3* |
| NA260 | 3.4,5.6,0.5,4.9 | 3# | UF221 | 2.5,5.6,0.3,5.1 | 12d |
| NA283 | 6.1,2.5,2.8,6.7 | 3# | UF613 | 6.0,3.5,0.8,6.2 | 3# |
| NA284 | 7.5,2.0,3.2,7.8 | 3# | UF667 | 2.6,3.7,0,4.0 | 3* |
| P4 | Variable | 12b | UIT1 | 2.0,6.2,0.4,3.8 | 74a,b,c,d,e |
| P7 | 2.0,7.2,0,4.0 | 3# | UIT2 | 1.6,6.7,0.3,4.2 | 12d |
| P12 | 4.1,4.9,0,6.5 | 2# | AMAZ15-15xAML | 4.2,3.9,1.0,5.9 | 3e |
| PA7 | 5.7,3.0,2.4,6.2 | 16d | AMAZ15-15xNA33 | 3.9,4.2,0.3,5.6 | 3e |
| PA13 | 4.1,4.5,0.8,5.3 | 39d,e | AMAZ15-15xUIT1 | 5.1,2.9,2.4,6.6 | 3e |
| PA76 | Variable | 12b | AMLxIMC67 | 3.4,3.9,0.3,5.1 | 3e |
| PA107 | 4.1,4.5,0.8,5.3 | 3* | AMLxNA33 | 4.8,3.5,1.8,6.4 | 3e |
| PA121 | 5.0,3.7,1.1,5.8 | 3* | AMLxUIT1 | 3.7,4.1,0,5.2 | 3e |
| PA127 | 6.2,2.7,2.5,6.7 | 3* | IMC67xNA33 | 4.2,3.6,0.7,6.3 | 3e |
| PA137 | 6.2,3.0,2.1,7.3 | 3* | IMC67xUIT1 | 4.5,3.7,0,5.4 | 3e |
| PA138 | 2.9,3.6,0,6.6 | 3 | NA33xUIT1 | 4.8,2.9,1.6,6.1 | 3e |
| PA149 | Variable | 3# | | | |

**(i)** PBC123 = Malaysian selections of unknown provenance probably Trinitario.
**Note:** The identity of planting materials in *italic* print is uncertain.

*Unless where indicated by an *, #, or certain of the lower case letters (see below and later discussion), the tests were based on monoclonal fermentations of 50 kg wet beans. * Refer to tests in which 3 kg samples of wet beans were inserted in fermentations of 50 kg of wet beans from BAL209. # Refer to tests of 0.75 kg samples of wet beans inserted in fermentations of 50 kg wet beans from diverse planting materials. The lower case letters refer to separate investigations undertaken as part of the main project. These were (a) effects of pod storage, (b) effects of fermentation time, (c) effects of pollen donor, (d) the development of the small scale (0.75 kg) fermentation procedure for flavour testing, and (e) inheritance of flavour characteristics. The main results of these separate trials are discussed later. Planting materials were generally tested as complete sets of six or more so that all were exposed to the same environmental conditions during fermentation and drying. BAL209, a cloned selection from a cross of PA35 with NA32, was included as a reference in most sets in every set in order to check the consistency of fermentation and flavour development, hence the number of replicate preparations of that particular planting material.*

**General Observations**

Although the above results reveal clear and consistent genetic effects on flavour, they understate the range of flavour differences that exists among the materials tested. The project was planned to allow the flavours of a wide range of planting materials to be screened over a relatively short period of time. Prior to the development of the small scale fermentation procedure, sample preparation was limited to periods of crop peaks which restricted the work to about 5 months each year. That was because the planting materials were tested as complete sets which required either 50 kg of wet beans of 6 genotypes from a single round of harvesting, or 300 kg of wet beans from a single harvest of BAL209 to serve as the fermentation medium for genotypes tested on the 3 kg scale.

Large numbers of samples therefore became available in batches and were screened for their dominant flavour characteristics. Whereas 3 replicate preparations were mostly sufficient to reveal differences in dominant characteristics, many more preparations would have been necessary to reveal significant differences in minor characteristics and would have restricted the project to a much narrower range of planting materials. Certain trends in minor flavour characteristics did emerge. A mild flavour impression, best described as smoky/phenolic, was observed in repeat preparations of certain Kerevat (K and KA), CC and UF clones. A spicy note, described also as coffee-like, was observed occasionally in some ICS clones. UIT1 and other cocoas with pronounced astringency were frequently described as musty/earthy. The smoky and musty/earthy flavours did not result from defective processing. They occurred in repeat preparations of the same or closely related planting materials and were not present in the other samples in the sets which had been subjected to exactly the same conditions of fermentation, drying and storage. The spicy/coffee-like notes and musty/earthy flavours were confirmed independently by other taste panellists.

**Effects of Pod Storage**

All planting materials were tested without pod storage. That was decided after trials had shown that effects of pod storage on flavour differed markedly between genotypes and because large scale storage is impracticable and was considered inappropriate to evaluation of germplasm. Results in Table 2 show the effects of 0, 5, 10 and 15 days pod storage on the flavours of AML, BAL209, NA33 and UIT1. The experiment was repeated three times and produced exactly the same result on each occasion.

**TABLE 2: EFFECTS OF POD STORAGE ON COCOA FLAVOUR ASTRINGENCY FOR FOUR GENOTYPES**

| Measure | Cocoa Flavour (i) | | | | Astringency (i) | | | | (-) Epicatechin mg/g | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days Pod Storage | 0 | 5 | 10 | 15 | 0 | 5 | 10 | 15 | 0 | 5 | 10 | 15 |
| AML | 7.1 | 6.3 | 6.3 | 7.2 | 3.7 | 3.9 | 4.1 | 3.4 | 6.1 | 5.9 | 5.1 | 3.3 |
| BAL209 | 4.3 | 5.4 | 6.5 | 7.7 | 6.2 | 5.1 | 4.1 | 2.9 | 20.4 | 5.1 | 0.8 | 0.5 |
| NA33 | 7.5 | 7.2 | 6.8 | 6.8 | 3.3 | 3.5 | 3.9 | 3.7 | 7.1 | 6.2 | 1.8 | 2.6 |
| UIT1 | 3.9 | 3.8 | 3.5 | 4.8 | 6.8 | 6.3 | 6.3 | 5.6 | 18.7 | 11.7 | 14.7 | 14.6 |

(i) Sensory scores on 10 cm line scale. Averages of 18 blind tests of each cocoa liquor.

Improvements in cocoa flavour have been attributed to reductions in pulp volume effected by post-harvest storage of pods or by pre-conditioning the pulp prior to fermentation (Biehl et al., 1990, Said et al., 1990). UIT1 had a thick and voluminous pulp which was markedly reduced by pod storage. Most of the change in pulp volume occurred between the fifth and tenth day. In contrast, the pulp of BAL209, which was very light and thin to begin with, was not appreciably altered. The changes in cocoa flavour were the exact opposite of the result which the two earlier considerations relating to differences in pulp volume would have predicted.

Analysis of the dried beans revealed differences in the concentrations of (-) epicatechin in the cotyledons which corresponded closely to the differences in astringency (Clapperton et al., 1992). Epicatechin and related oligomeric polyphenols extracted from unfermented beans of UIT1 were similar in astringency to cocoa liquors prepared from UIT1 and BAL209 without pod storage. The pod storage treatments of BAL209 resulted also in a gradual darkening of the cocoa liquors and a stepwise increase in physical viscosity and mouthfeel. The same occurred to a lesser extent between 10 and 15 days pod storage of UIT1. These are further indications of changes in the polyphenols of the cotyledons, possibly as a consequence of differences in polyphenol oxidase activity. For whatever reason, the rates of change clearly differ between genotypes. Differences in the condition of the cotyledons, which cannot be predicted from the appearance of the pods at the time of harvesting, might be the reason for the variations in flavour between replicate preparations of certain genotypes (see Table 1). The flavours of IMC67 and PBC123 were improved slightly by 5 and 10 days pod storage, but not so dramatically as in BAL209. On occasions when ICS95 (normally similar in colour, flavour and viscosity to UIT1) developed more cocoa flavour the liquors were also darker and more viscous. The more developed cocoa flavours of ICS95 had fragrant and spicy (cinnamon-like) characters which in other trials have resulted from pod storage treatments (Arikiah et al., 1994; Yanamoto, personal communication).

The results in Tables 1 and 2 show an almost perfect inverse correlation between scores for cocoa flavour and astringency, and there is very high correlation also between cocoa flavour and viscous mouthfeel. To a certain extent the strengths of these correlations are a direct effect of the primary taste testing being carried out by a single taster. Although coded samples were tasted blind throughout, it is extremely difficult to avoid associations between characteristics in replicate tests of more than 800 cocoa liquors. If these strong associations demand the use of a single sensory term, astringency would be the preferred choice. Differences in astringency have been confirmed separately by independent panels more so than differences in cocoa flavour intensity. There is also the evidence from the instrumental-analytical estimates of epicatechins (Table 2) that the differences in astringency are real. On the other hand, the associations between cocoa flavour, astringency and viscosity may be indicative of a relatively simple biochemical relationship between polyphenols and these qualitative characteristics.

**Effects of Fermentation Time**

Effects of 3, 5 and 7 days fermentation were examined in search of an explanation of variable flavour development of IMC67, P4 and PA76. (Flavour scores for IMC67 are entered in Table 1 to allow comparison with later scores for progeny). Marginal increases in raw/beany flavour, indicative of underfermentation, resulted from the 3 day fermentations, and there were no appreciable differences in flavour between the 5 and 7 day fermentations. In earlier trials of UIT1 there were little or no differences in flavour between 3 and 5 day fermentations. (Clapperton et al., 1994). All of the results in Table 1 refer to fermentation for 5 days with a single turn at the end of the second day.

**Effects of Pollen Donor**

Apart from a series of trials on BAL209 and UIT1, all of the cocoas were open pollinated. In the separate tests of BAL209 and UIT1, flowers were pollinated manually using pollen from CC10 and NA33 with strongly contrasting flavours. BAL209 was also self pollinated. There were no consistent effects on flavour between these different pollination treatments in six replicate trials, and the flavours of both BAL209 and UIT1 were indistinguishable from samples which had been open pollinated. All six sets of UIT1 showed clear and consistent differences in bean size between the use of CC10 and NA33 as pollen donor, which proved that the manual pollination had been effective (Clapperton et al., 1993). The result indicates that flavour is the property of the mother tree alone which should facilitate flavour testing of cocoa germplasm in other collections and environments.

**TABLE 3: MONOCLONAL AND MIXED FERMENTATIONS OF SCA12 AND UIT1**

| Genotype | Fermentation | Cocoa Flavour | Astringent | Fruity Flavour |
|---|---|---|---|---|
| SCA12 | Monoclonal<br>Mixed | 6.1<br>5.9 | 3.7<br>3.6 | 4.8<br>5.1 |
| UIT1 | Monoclonal<br>Mixed | 3.3<br>3.1 | 5.8<br>6.2 | 0.2<br>0.2 |

**Development of Small Scale Fermentation Procedure for Flavour Testing**

The small scale test requiring 0.75 kg wet beans, i.e., from 6 to 8 pods, was developed following a stage of the work when we questioned if the effects of genotype on flavour were real or if we were being misled by differences in bean size affecting conditions of fermentation and drying. Trials were planned based on UIT1 and SCA12 which differ markedly in bean size and flavour. UIT1 has a bean count of about 55/100g, whereas SCA12 is nearer to 120/100g. It was postulated that the difference in flavour between UIT1 and SCA12 resulted from effects during fermentation and drying caused by the different packing arrangements of the beans. The larger beans of UIT1 would pack more openly and by allowing freer access of air might ferment and dry more rapidly. The low cocoa flavour of UIT1 might therefore result from over-fermentation and its sharper taste from the retention of acids as a consequence of the faster drying (Duncan et al., 1989). These possibilities were tested by fermenting and drying an intimate 50-50 mixture of the two genotypes. Samples of UIT1 and SCA12 were separated by hand from the mixture of dried beans for comparison with cocoas from monoclonal fermentation of the two genotypes. The experiment was repeated three times. The flavours of the two genotypes were not affected by the change in composition of the fermentation medium (Table 3).

Following these observations, 13 genotypes with contrasting flavours were selected to test a procedure which required only 0.75kg of wet beans and used beans from mixed planting materials as the fermentation medium. The 13 genotypes were inserted in sets of 4 in fermentations of 47kg wet beans from NA33, UIT1 and mixed planting materials. Complete sets of 13 fermentations with the same fermentation medium were run simultaneously. Each one contained 0.75kg samples of four different genotypes according to the following 13 x 4 experimental test design.

| Fermentation | Genotype | | | |
|---|---|---|---|---|
| I | 1 | 2 | 4 | 10 |
| II | 2 | 3 | 5 | 11 |
| III | 3 | 4 | 6 | 12 |
| and so on through to | | | | |
| XIII | 13 | 1 | 3 | 9 |

The design allowed each genotype to be fermented with every other, as in fermentations 1, 5, 11 and 13 which included genotype 1.

| Fermentation | Genotype | | | |
|---|---|---|---|---|
| I | 1 | 2 | 4 | 10 |
| V | 5 | 6 | 8 | 1 |
| XI | 11 | 12 | 1 | 7 |
| XIII | 13 | 1 | 3 | 9 |

After fermentation and drying, the four samples of each genotype were combined as a single sample. Each genotype had therefore been fermented in direct contact with every other and in the three different fermentation media. The entire experiment was repeated three times. Scores for cocoa flavour intensity are shown in Table 4.

There are two separate categories of flavour, with NA33, PA7, SCA12 and PBC123 in one and BAL209, CC10, K82, UF221, UIT1 and UIT2 in the other. The classification can almost be made by inspection on the basis of non-overlapping ranges of scores and is clearly confirmed by analysis of variance. It agrees exactly with flavour tests of K82 and UF221 made on the 3kg scale of fermentation and with 50kg monoclonal fermentation of the other eight genotypes. There were no consistent effects of the different fermentation media on flavour development. The 0.75kg test now employs wet beans from mixed planting materials as the fermentation medium, thereby eliminating entirely the need for large numbers of trees of a single genotype, either to provide sufficient wet beans for the test or to serve as the fermentation medium.

Variable flavour development of PA13, KA5-201 and ICS95 was not attributable to one or other of the fermentation media. As discussed earlier, the variability probably related to an unrecognisable factor in the plant materials selected for the test. The use of fewer pods for a flavour test makes selection for uniformity of ripeness and other conditions more critical.

**TABLE 4: MEANS AND RANGES OF SCORES FOR COCOA FLAVOUR INTENSITY FOR THIRTEEN GENOTYPES FERMENTED IN WET BEANS FROM DIFFERENT PLANTING MATERIALS (FERMENTATION MEDIUM) (i)**

| Genotype | Fermentation Medium | | |
|---|---|---|---|
| | **NA33** | **UIT1** | **Mixed Planting Materials** |
| BAL209 | 2.6 (1.7-3.8) | 3.0 (2.1-3.7) | 3.2 (2.2-4.0) |
| CC10 | 2.1 (0.8-3.7) | 1.8 (0.9-3.2) | 2.1 (1.6-3.4) |
| ICS95 | 1.9 (0.7-3.3) | 4.2 (0.5-7.3) | 2.5 (0.8-4.0) |
| K82 | 2.9 (1.2-4.2) | 2.4 (1.2-4.2) | 2.7 (1.2-4.3) |
| KA5-201 | 5.3 (3.4-7.1) | 4.3 (1.4-7.2) | 3.9 (2.4-5.0) |
| NA33 | 7.0 (5.8-8.2) | 7.3 (6.8-8.1) | 6.8 (6.0-7.5) |
| PA7 | 5.1 (3.9-7.2) | 5.2 (4.5-6.3) | 5.1 (3.7-6.6) |
| PA13 | 4.5 (2.0-5.8) | 5.4 (2.8-7.7) | 3.2 (2.2-4.0) |
| PBC123 | 6.5 (4.5-8.0) | 7.1 (6.1-7.9) | 6.6 (6.1-7.4) |
| SCA12 | 6.4 (4.9-7.6) | 6.9 (6.0-7.8) | 6.3 (5.4-8.2) |
| UF221 | 1.6 (0.9-2.7) | 1.9 (1.2-3.3) | 2.1 (1.0-5.0) |
| UIT1 | 1.3 (0.7-1.8) | 1.7 (0.8-2.8) | 1.2 (0.4-2.4) |
| UIT2 | 1.3 (0.7-2.8) | 2.0 (1.2-3.3) | 1.6 (0.7-3.0) |

(i) N=12 from 3 replicate preparations in each medium with 4 blind taste tests of each liquor.

## Inheritance of Flavour Characteristics

Flavour characteristics are heritable but are expressed in fruit from the first generation of seedlings, not in the beans that result from the initial act of pollination (Clapperton et al., 1993). Flavour scores for the 10 progeny in the last column of Table 1 are mostly between the values for the respective parents. The inheritance of flavour characteristics is now being tested more rigorously following the development of the small scale fermentation procedure (c, above) which allows the flavour test to be applied to fruit from single trees. Preliminary tests of individual progeny from SCA9 crossed with PA13 indicate that the flavour characteristics are not only heritable but are segregated among progeny. Further testing is currently in progress to clarify the nature and extent of the flavour differences between progeny.

## SUMMARY AND CONCLUSIONS

These results shed new light on the origins of cocoa flavour development, as well as providing an explanation of how cocoa flavour has altered as the market has grown and new centres of production have been developed. Development of seedlings or clonal cocoas without flavour selection means that flavour will tend towards an average quality and that distinctive flavours on which earlier developments of the industry were based may be lost. The current work on the inheritance and segregation of flavour characteristics could arrest or even reverse that trend.

Adoption of genetic flavour potential as a selection criterion is dependent on clear guidelines from the consuming industry as to the required sensory profiles and agreement on the associated flavour references. If, as is likely, there are several profiles, breeders will require knowledge of market shares and values, so that flavour can be given an appropriate weighing in an economic selection index.

The flavours encountered in this study were cocoa or its apparent masking by astringency, fruity/floral a weak smokiness and occasional spiciness. The cocoa/astringent and fruity/floral taints are heritable. The 95 clones introduced to BAL Plantations, Malaysia from International Cocoa Genebanks are drawn from perhaps 30 to 40% of the known ecotypes which would be represented in a core collection of cocoa germplasm. The limited variations within ecotypes such as IMC and NA supports the concept of a core collection. Laying aside the true Criollo, such as the Porcelana and Nacionals with their known sensory traits, the representatives of the collection rises sharply, the main omissions being the Brazil, Colombia and Guyana populations. The inference is that once flavour is included in an economic selection index, breeders will make more progress through recurrent selection than further surveys of germplasm within appropriate populations.

Historically, chocolate manufacturers have been inconsistent in presentation of their requirements to cocoa breeders and growers alike. One of the difficulties is that manufacturers do indeed have different flavour requirements, but until now there has also not been any agreed methodology for "Preparation of Samples for Cocoa Flavour Tests" or "Taste Test Procedures". Proposed Standard Methodology for these resulting from this work at BAL is attached to this article as Appendix 1 and Appendix 2 respectively. We hope that these will become standard ways for the industry to assess and publish results of cocoa flavour work.

## REFERENCES

*Arikiah, A., Tan,Y.P., Sharma,M. and Clapperton,J.F.* (1994) Experiments to Determine Influence of Primary Processing Parameters and Planting Material on the Flavour of Cocoa Beans in Malaysia. Cocoa Growers' Bull., **48**, pp.36-46.

*Biehl,B., Meyer,B., Said,M.B. and Samarakoddy,R.J.* (1990) Bean Spreading: A Method for Pulp Pre-conditioning to Impair Strong Nib Acidification during Cocoa Fermentation in Malaysia. J. Sci. Food Agric., **51**(1), pp.35-45.

*Clapperton,J.F., Yow,S.T.K., Chan,J., Lim,D.H.K., Lockwood,G., Romanczyk,L. and Hammerstone,J.F.* (1991) The Effects of Cocoa Genotype on Flavour. Proceedings of the International Cocoa Conference, Challenges in the 1990s, Kuala Lumpur. Malaysian Cocoa Board, Kota Kinabalu, pp.468-478.

*Clapperton,J.F., Romanczyk,L., Hammerstone,J.F., Yow,S.T.K., Lim,D.H.K. and Lockwood,G.* (1992) Polyphenols and Cocoa Flavour. Proceedings of Meeting of Groupe Polyphenols, **16**(II), pp.112-116.

*Clapperton,J.F., Yow,S.T.K., Lim,D.H.K. and Lockwood,G.* (1993) Genetic Variation in Cocoa Flavour. Proceedings of 11th International Cocoa Research Conference, Yamoussoukro, in press.

*Clapperton,J.F., Yow,S.T.K., Chan,J., Lim,D.H.K., Lockwood,G., Romanczyk,L. and Hammerstone,J.F.* (1994) The Contribution of Genotype to Cocoa (Theobroma cacao L.) Flavour. Trop. Agric. (Trinidad), **71**(4), pp.304-307.

*Duncan,R.J.E., Godfrey,G., Yap,T.N., Pettipher,G.L. and Tharumarajah,T.* (1989) Improvement of Malaysian Cocoa Bean Flavour by Modification of Harvesting, Fermentation and Drying Method - the Sime/Cadbury Process. The Planter, Kuala Lumpur, **65**, pp.157-173.

*Said,M.B., Jayawardena,M.P.G.S., Samarakoddy,R.J. and Perera,W.T.* (1990) Pre-conditioning of Fresh Cocoa Beans Prior to Fermentation to Improve Quality: A Commercial Approach. The Planter, Kuala Lumpur, **66**, pp.332-345.

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## APPENDIX 1: PROPOSED STANDARD METHODOLOGY FOR PREPARATION OF SAMPLES FOR COCOA FLAVOUR TESTS

**Harvesting and Fermentation**

Collect sufficient pods from a single harvest to provide 50, 3 or 0.75kg of wet beans in good condition. Discard all damaged pods. Break the pods the next day and separate the wet beans from all pieces of husk and placenta. Discard all damaged and discoloured beans. Start the fermentation as soon as possible after the pods have been broken. Use a rigid former with a capacity of 50kg wet beans and an open-weave construction to keep the surface to volume ratio of the fermentation heap constant. At BAL Plantations inverted plastic laundry baskets strengthened with hoops of rattan were used. The dimensions of the baskets were 50cm (maximum) diameter, 38cm (minimum) diameter and 48cm deep. Place the basket on a sloping tray lined with fresh banana leaves to allow sweatings to drain freely. After filling, cover the basket with fresh banana leaves to retain some of the heat of the fermentation and to keep out rainwater and other unwelcome intruders. Record the temperature at the centre of mass of the fermentation at the beginning and subsequently every 24h. After 48h, empty the basket, mix the beans thoroughly and refill the basket. Replace all the banana leaves with fresh ones. Allow the fermentation to continue undisturbed, apart from temperature recording, for another 72h.

In the trials which used 3kg of wet beans, the test sample in a nylon net bag (24x51cm, 5mm mesh, 1.0mm thread diameter, 220g per square metre) was placed in the centre of mass of a fermentation of 50kg wet beans of BAL209 which served as a standard fermentation medium. Because there is no effect of the pulp composition on the flavour differences between planting materials (see main text) wet beans from mixed planting materials can now be used as the fermentation medium.

For inheritance testing in which the 0.75kg test was applied to fruit from single trees, sets of 5x0.75kg samples, comprising 3 progeny and both parents, in nylon net bags (17x34cm, 5mm mesh, 0.7mm thread diameter, 90g per square metre) were inserted in fermentations of 50kg of wet beans from diverse planting materials, thereby allowing parents and progeny to be compared directly.

**Drying**

After fermentation, dry the beans in the sun or in a current of air at ambient temperature to 7.5 to 8% moisture. A source of indirect heat may be used to prevent or limit mould growth in the event of continued wet weather. The temperature of the air onto the beans should not be above 40°C until the moisture content of the beans is below 20%. Be careful to avoid smoke or mineral oil contamination from fumes if artificial drying is used.

**Liquor Preparation**

Store the dried beans in new jute sacks for 12 to 16 weeks to allow the beans to stabilise prior to liquor preparation. Roast 330g of dried beans from a coned and quartered sample at 145°C for 30 minutes. Break and winnow the beans to remove the shells. Use a coffee mill for a few seconds only to reduce the nibs to fine particles then transfer them to an end-runner mill and mill for 90 minutes until the nibs are turned into liquor. The milling process will generate its own heat and no direct heating is necessary. Store the liquors at -18°C until there is a complete set ready for tasting.

In the project at BAL Plantations, sets generally comprised 5 different genotypes and a reference cocoa (BAL209) which were fermented and dried as a complete set so that all were exposed to the same environmental conditions throughout. The reference provided a link between different sets and a means of checking that flavour development was normal.

## APPENDIX 2: PROPOSED STANDARD METHODOLOGY FOR TASTE TEST PROCEDURES

Wherever possible liquors were tested in sets of 7 or 13. Sets of 7 comprised the 5 genotypes and the reference sample of BAL209, which had been fermented and dried together, plus a flavour reference liquor which had been prepared in bulk beforehand and stored at -18°C. Sets of 13 comprised two sets of 6 and one sample of the flavour reference, or a set of 13 liquors from the development work on the 0.75kg scale test (see main text). The flavour reference serves as a hidden control to check the reliability of the sensory testing. Provided scores for the reference fall within specified limits they can be used to correct minor differences in the use of the scales between different series of sensory tests.

Use a 7x3 or 13x4 incomplete block experimental design in which the liquors are tasted in sets of either 3 or 4 respectively. For a 7x3 test, code the liquors randomly from 1 to 7 and allocate three 2-digit random codes to each liquor. Lay out the 21 liquors in sets of 3 according to the following design:

| Set | Liquors and (Codes) | | |
|---|---|---|---|
| I | 1 - (34) | 2 - (26) | 4 - (74) |
| II | 2 - (82) | 3 - (18) | 5 - (91) |
| III | 3 - (44) | 4 - (19) | 6 - (80) |
| IV | 4 - (28) | 5 - (55) | 7 - (67) |
| V | 5 - (33) | 6 - (71) | 1 - (21) |
| VI | 6 - (49) | 7 - (22) | 2 - (75) |
| VIII | 7 - (93) | 1 - (82) | 3 - (38) |

Ask a colleague to code and lay out the samples. The order of sets should then be randomised, or other arrangements made to provide a double blind test.

Melt the liquors at about 55°C and mix them thoroughly to correct any fat separation. They should then be presented on a hot plate or in a hollowed out aluminium block at between 40 and 45°C for tasting. Use red or reduced illumination to mask any colour differences between the liquors.

Starting with any set, taste all 7 in random order. The liquors should be tasted from left to right as indicated in the design. That ensures that each liquor is tasted once as the first sample, once as the second and once as the third, thereby providing a certain balance of carry over effects between successive liquors. Allow sufficient time for flavours to clear and the palate to recover between sets. A mouthwash of warm water helps. Nothing stronger. Before embarking on a series of taste tests it is helpful to taste a set of three samples as a warm up. These can either be the three extreme flavours in the entire set, one of the sets of three liquors; or any three liquors selected at random.

Each panellist must taste all 7 sets. Intensities of flavour characteristics are scored on 10cm line scales. Encourage panellists to use the full extent of the scales (see following section on the use of references to illustrate the meaning of terms and use of the scales). Use analysis of variance to assess scores for individual terms by individual panellists*. Do not reveal codes or results until all analyses have been completed. Retain data on single terms that differ significantly between the test samples at or beyond 95% confidence. If directional but not statistically significant differences are recorded, the test samples should be recoded and the entire test repeated. Combine the results of the two tests by each individual panellist. If after 6 blind tests of each liquor the differences are still not statistically significant, it is reasonable to conclude that the panellist has failed to detect a difference between the test samples. Combine data from individual panellists, each selected according to the above criterion, to obtain a panel result. Do not combine data from panellists who have different perceptions of the test samples or different interpretations of the meanings of the terms. The best way of checking that is to plot the results.

In the 13x4 test liquors are tasted in sets of 4. The lay out follows a similar pattern to that given for the 7x3 test. The first line of the design reads - Set I, liquors 1,2,4,10 and the last - Set XIII, liquors 13,1,3,9. Again, taste the sets in random order with all the appropriate coding of samples and disciplines as outlined for the 7x3 test. Data analyses are based on 4 blind tests of each liquor, or on 8 blind tests if the 13x4 test is repeated.

**Terminology and References**

Terminology of test forms should be restricted to characteristics that can be defined and are actionable. That leads to the use of physical flavour references in the form of cocoa liquors with flavours that can be reproduced from selected planting materials by controlled processing treatments.

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* Measurement of the scales can be tedious without the help of a system for automated measurement or recording. Category scales can be used instead of the line scales. Work is in hand to produce a simpler method of data analysis based on sums and ranges of scores which gives the same general result as analysis of variance of the scores on the line scales. Examples of a line scale for cocoa flavour intensity and a category scale for astringent are given below. Intensities increase from left to right on the scales. Panellists place a vertical mark on the line scale or tick a box of the category scale.

Cocoa flavour intensity ----------------------------------------

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Astringent | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

The following terms cover the majority of cocoa flavour characteristics and are listed together with cocoa liquors which may be used to illustrate the meanings of the terms and use of the scales. The use of a colour chart to define differences in the colour of cocoa liquors is also suggested.

| Term | Meaning, Synonyms, Reference Cocoa Liquors and Use of the Scale |
|---|---|
| Cocoa flavour intensity | Affected by both genotype and process. References (High scores): CC41, NA33. Low scores: CC10, K82, UIT1. |
| Acid/sharp | Sharp, pungent smell and immediate sharp taste, vinegar. High scores: Beans from 5 or more days fermentation fast dried at >60oC. Low scores: Sun dried and under-fermented cocoas. |
| Astringent | Mouth drying/puckering. Affected by both genotype and degree of fermentation. Develops slowly (see also late sour). High scores: UIT1, BAL209 without pod storage. Low scores: CC41, NA33, BAL209 with 10 or 15 days pod storage. |
| Bitter | Taste of quinine, caffeine and theobromine. Taste develops slowly at back of the tongue. Genotypes differ in caffeine and theobromine content. |
| Raw/green | Characteristic (beany) flavour of unfermented cocoa beans which are also astringent and bitter. High scores: Liquors made from unfermented or slaty beans. Mid-scale scores: Under-fermented beans. Zero scores: Fully fermented beans. |
| Fragrant | Sweet aromatic character of cocoa flavour. Increased by post-harvest pod storage. High scores: NA33, PBC123, BAL209, all with 10 or more days pod storage. Low scores: Same genotypes and other cocoas without pod storage. |
| Fruity | Dried fruit, raisins, currants, dates, prunes. High scores: CC41, SCA6, SCA12. |
| Late sour | The gradually developing astringency or sourness of under-ripe fruit and vegetables, eg. mango. The time scale effect distinguishes it from acid sourness. High score: UIT1. |
| Viscous/thick mouthfeel | A physical viscosity and mouthfeel effect. High scores: CC41, NA33, SCA12, all without pod storage, BAL209 with 10 or more days pod storage. Low scores: UIT1, BAL209 without pod storage. |
| Musty/earthy | High scores: Damp cocoa with marked external mould growth. Low to mid-scale scores: UIT1 and other genotypes with very high levels of astringency. |
| Smoky | An effect of careless drying or storage. Wood smoke, pungent, phenolic. High score: Wet cocoa dried over a smoking wood fire (may have to be diluted to taste with uncontaminated beans). Zero score: Sun dried cocoas not exposed to wood smoke during processing and subsequent storage. |
| Putrid (over-fermented) | Rank. High score: Cocoa fermented for 12 days and turned every day or every second day, followed by interrupted drying. |
| Sacky | Baggy, burlap. Cocoa in prolonged contact with damp jute sacks. |
| Colour differences | Develop colour chart to cover differences between CC41, PBC123, NA33 and SCA12 (dark brown) and CC10, ICS60, K13, 10P, UF227 and UIT1 (pale brown) liquors. |

The use of physical references to anchor the meanings of terms allows the flavour characteristics to be described in the local language, thereby increasing the accuracy of perception. Indonesian panellists had difficulty in recognising unfermented cocoa flavour until the term "kacang mentah" in Bahasa (meaning freshly harvested peanut) was introduced.

To prevent flavour terminology from running amok and being "developed" out of control, additional terms should not be added to the list until a suitable reference is available to define the meaning of the term and to relate it to a reproducible method of preparation.

It is proposed that the foregoing methodology will give the opportunity for cocoa researchers in cocoa producing countries to assess the expected reactions from cocoa users in a reproducible manner. We recommend its widespread adoption.

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### AUGUST 1994

**The world cocoa market: an analysis of recent trends and of prospects to the year 2000. A study of the secretariat of the International Cocoa Organisation (ICCO)**
International Cocoa Organisation, London, UK, pp.185; January 1993
During the past decade the world cocoa market was characterised by excess production, resulting in a persistent build-up of stocks and the collapse of prices. A summary review of major developments in the world cocoa market over the last few years is given. The fundamental structures and relationships which operate within the world cocoa markets are described. The results derived from the production models of the principal cocoa-producing countries and the estimation results of the consumption models are provided. The projections relating to stocks and prices, and the conclusions reached are presented. The features of the various models used are described in greater detail in the annex.

### OCTOBER 1994

**[Effect of altitude on fermentation]. Efecto de la altitud sobre el proceso de fermentation**
CUBERO,E., ENRIQUEZ,G., HERNANDEZ,A. and RODRIQUEZ,T. Centro de Investigacion en Productos Naturales, Universidad de Costa Rica, San Jose, Costa Rica - *Turrialba (ICCA)* v.42(3), pp.294-298; July 1992
In Costa Rica in 1988, 16 samples were taken of 4 cocoa varieties, 2 of fine and 2 of bulk cocoa, both fermented and on fermentation. The samples were from 2 different altitudes. Ten chemical analyses were used to determine the effect of altitude from 40m above sea level (masl) showed more severe changes than those from 600 masl, except for pH and total acidity. The room temperature at altitudes near sea level assisted in reaching higher temperatures during fermentation, which could also be maintained longer than the temperatures reached at higher altitudes. Chemical reactions and other changes during fermentation were shown to be more rapid.

**Organic acids in cocoa beans: a review**
JINIAP,S. Department of Food Science, Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia - *ASEAN Food Journal (Malaysia)* v.9(1), pp.3-12; January 1994
A review is presented on the organic acids occurring in cocoa beans. Cocoa beans contain about 0.47-1.02% volatile and 1.01-1.88% non-volatile acids (dry weight). The volatile acids include acetic, propionic, butyric, isobutyric and isovaleric acids, whereas the non-volatile acids include oxalic, citric, malic, succinic, lactic and tartaric acids. These acids are developed mainly through the activities of various micro- organisms in the pulp, and then diffuse into the bean (cotyledon) during fermentation. Aeration, mass and period of fermentation, and the type and duration of heat applied during drying are the main factors governing final pH titratable acidity and concentration of acids in commercial

beans. The volatile acids are also affected during bean roasting and chocolate conching. The accummulation of the acids during fermentation provides an acidic environment for bean death and enzymatic reactions leading to development of flavour precursors. The residual acid determines the acidic taste of the products. Acetic acid and lactic acids are probably mainly responsible for the acidic taste in the final products.

**[Cocoa quality in four cocoa growing regions of Costa Rica]. Calidad del cacao en cuatro zonas cacaoteras de Costa Rica**
CUBERO,E., ENRIQUEZ,G., HERNANDEZ,A. and RODRIQUEZ,T. Centro de Investigacion en Productos Naturales, Universidad de Costa Rica, San Jose, Costa Rica - *Turrialba (ICCA)* v.42(3), pp.287-293; July 1992
In Costa Rica during 1988 and 1989, 94 samples were collected during the rainy season and 72 during the dry season from 4 areas (north, south, central Pacific and Atlantic zones). Three analyses were used to determine the fermentation of these samples. The results were compared with established values obtained in previous research. Additionally, 5 other analyses were used to complement the information. The central Pacific zone was the area where cocoa had the highest fermentation percentage. Since this area had only recently begun to produce cocoa, the cocoa planters were using improved fermentation techniques. The southern zone showed the poorest quality of cocoa, due to the use of plastic bags to drain the pulp from the seeds before drying. Some large cocoa planters and co-operatives had adequate methods of fermentation, and produced cocoa of excellent quality; however, such planters represented only 12% of the total evaluated production.

## NOVEMBER 1994

**International cocoa agreement, 1993**
UNCTAD, Geneva, Switzerland, pp.44; 1993
The objectives of the International Cocoa Agreement, 1993 are: to promote the development and strengthening of international co-operation in all sectors of the world cocoa economy; to contribute to stabilisation of the world cocoa market in the interest of all members; to facilitate the expansion of international trade in cocoa; to promote transparency in the working of the world cocoa economy; to promote scientific research and development in cocoa and to provide a forum for the discussion of all matters related to the world cocoa economy. In addition to the objectives and definitions, the following subjects are covered: constitutional provisions; financial provisions; economic provisions; market-monitoring and related provisions and other provisions. Tables are presented showing exports and imports of cocoa by different countries from 1989/90 to 1991/92.

## DECEMBER 1994

**Utilisation of cocoa-pod pericarp fractions in broiler chick diets**
SOBAMIWA,O. and LONGE,O.G. Cocoa Research Inst. of Nigeria, Ibadan, Nigeria - *Animal Feed Science and Technology (Netherlands)* v.47(3-4), pp.237-244; June 1994
The proximate composition, non-starch polysaccharides plus lignin and mineral components of cocoa pod husk (CPH) and its layers (epicarp, mesocarp and endocarp) were determined in Nigeria. Each material was incorporated at 0%, 5% and 10% levels

in isoprotenious broiler starter diets. Each diet was fed to duplicate groups of 10 1-day-old broiler chicks for 4 weeks. The husk had high proportions of total ash (>9%), crude fibre (>20%), cell-wall contents (11% hemicellulose, 35% cellulose, 15% lignin and 6% pectin) and mineral elements (3.18% K, 0.32% Ca and 0.15% P). The epicarp was the most lignified layer and had the highest amounts of total ash, C, K, P and other inorganic elements. The mesocarp had the bulk of the crude fibre (approx. 50%) and cellulose contents. The endocarp, although most balanced in proximate components, contained about 60% of the pectic substances. In the feeding trial, both levels (5% and 10%) of the epicarp depressed weight gain and feed efficiency. Apparent dry matter utilisation was reduced in all tests with inlcusion at 10% level. Gizzard weight tended to increase with the mesocarp diets, while the intestine was longer with the 10% epicarp diet. The epicarp (outer pericarp) is the most limiting portion of the CPH. It is not the fibre quantity per se but the components (principally lignin and pectin, probably acting jointly in an adverse manner) that inhibit the utilisation of CPG in broiler diets.

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