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Master Thesis
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The Analysis of the drying behaviour, the Quality changes and the sugar kinetics during the drying process of Indonesian Cocoa

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SUMMARY

The harvest of 2001/02 the world production of cocoa beans is estimated at 2.818.000 t. Cocoa production in the past decades became more and more important for Indonesia. Since 1950/51, Indonesia has increased its raw cocoa production from less than 1000 t to 450.000 t by the cocoa year 2001/02. Nowadays it is the second cocoa producing country of the world. Its′ cocoa production mainly consists of "Bulk Cocoa", which is exported to industrialized countries where it is roasted and processed for consumption. "Bulk Cocoa" has attributes of weak flavour and high acidity, which are the main reasons for price deductions on the world market. This burden is carried by the small to medium scale cocoa farmers.

The quality defects of Indonesian "Upper Amazon Hybrid" are accounted to the high pulp quantity per seed in comparison to the West-African "Amelonados". This attribute is mainly the reason for high acid concentrations during fermentation. High acetic acid concentration overlies the other aroma consituents. In former decades Indonesian cocoa producers planted "Amelonados" but these plantings were replaced by the pest resistant "Upper Amazon Hybrid".

Cocoa passes many processing steps before reaching the consumer. After harvest, and fermentation, drying takes place in the countries of origin. Once it is dried it is transported and stored prior to processing. In roast houses raw cocoa is roasted and processed to confectionery or food additives. During mentioned postharvest operations negative genotypic attributes can be corrected to a certain degree.

The Indonesian government powered the cocoa production by transmigration and cocoa dissemination programmes since the 1960′s. The Indonesian agricultural sector for cocoa production is characterized by small to medium scale farmers (1-2 ha), that produce more than 80 % of the country cocoa output. Between farmers and consumers middleman and traders earn the majority of the final cocoa price. The agricultural structure and cocoa pricing politics, are the main reasons why farmers are not incentived to ferment cocoa. If fermentation is carried out, it is often done insufficiently. Smallholders cocoa is sun dried on by bare soil, mats or pavement, with temperatures between 30-50 °C to moisture contents of 15-20 %, before selling to middlemen. Usually sun drying to moisture contents of 7 % deliver the best quality results, when weather conditions favour drying. During rainy season or rainy days drying process is slowed down by remoistening, leading to mould or product decay influencing negatively the quality by mould. Further drying on bare soil might lead to contamination by animal droppings. Once cocoa reaches the middlemen it is priced according to weight and not to quality. The middlemen dries the cocoa up to moisture content values of 10-12 % by sun drying. Traders dry cocoa by artificial drying to storable and transportable moisture content values of 7 %. By drying the cocoa with artificial methods cocoa can be contamined by combustion gases of the dryer. The genotypic features of "Bulk Cocoa" and lack of fermentation procedure lead to a raw cocoa product with weak flavour and high acidity attributes. Along with quality defects, large distances to domestic markets and small daily yields make it even more difficult to improve the quality.

An integrated cocoa processing system, the "Solar Processing Centre" comprising fermentation and drying sections, was developed in order to cope with quality losses of cocoa. These system was mainly developed for farmers organized in cooperatives. The fermentation section consists of fermentation boxes arranged in a cascade system. Whereas the drying section comprises a roof integrated solar air heater and a biomass furnace. Its cocoa processing capacity ranges between 100-150 farmers. By this, proper fermentation and drying to 7 % moisture content can be carried out at low costs. In addition the "Solar Processing Centre" can be used also for drying of other agricultural products, like coffee and grain. Farmers organized in cooperatives are able to enter the market with bigger quantities and achieve better prices in comparison to single farmers. Ensuring on the long run the living standard of smallholders.

Fermentation as one keystone of postharvest operations, improves the cocoa aroma by formation of aroma precursors like amino acids and reducing sugars. During fermentation, drying and especially roasting, reducing sugars and amino acid react to cocoa typically "Amadori compounds"by passing the Maillard reaction. Previous studies, which achieved good results dealt mainly with fermentation and drying of cocoa in thick or thin layers. PASS studied the fermentation, the drying behaviour of cocoa and quality changes during the process [48]. In order to cope with the acidity of cocoa RITTERBUSCH developed by analysing in depth the fermentation process a circulating air fermentation system [43].

The main aim of drying is to stop the biochemical activity of the fermentation process by reducing 50-60 % moisture content to a storable value of 7 %. This not only stops the biological and chemical activity of the fermentation process, it also contributes to aroma formation. Depending on the drying air temperature regime, aroma constituents are preserved or consumed by biochemical reactions in the seed. It was observed that concentration of reducing sugars decreases more at higher, than at lower drying air temperatures. As they are the main limiting factor for aroma development, drying aims to preserve reducing sugars contents. In former research works conducted by PASS and MÖNDEL drying behaviour of cocoa considering quality changes was studied [48,81]. Drying trials in these studies consisted of monitoring the effect of single stage and two stage drying towards duration of drying and cocoa quality. Their studies concluded that drying with temperatures above 70 °C had a negative effect on the aroma development, because of fast reduction of reducing sugars and diminished acetic acid volatilization. Due to its prolonged 50 °C phase at the beginning, two stage drying led to better quality results than single stage drying. Drying by implementing a two stage drying temperature regime stops fermentation slowly, ensuring a complete hydrolysis of sucrose into glucose and fructose. High concentrations of glucose and fructose after drying ensures a good aroma yield during the roasting process. Mould and overfermentation are suppressed by increasing the temperature of two stage drying after predrying at 50 °C.

In order to gain detailed information for deeper understanding of the sugar and acetic acid development during the drying process, further research is necessary.The aim of this study was to analyse the drying behaviour, the quality changes and the sugar kinetics of cocoa by implementing two stage drying of thicklayers and one stage-single layer drying as reference drying. These research work comprises also the application of results gained in the laboratory on the work with the SPC.

The drying trials were conducted at the INDONESIAN COFFEE AND COCOA RESEARCH INSTITUTE (ICCRI) in Jember/East Java and at COMEXTRA MAJORA company area in Wotu/South-Sulawesi. For the trials "Upper Amazon Hybrids"was supplied by the plantation PT GLENMORE and the plantation of COMEXTRA MAJORA.

Before fermentation the pulp seed ratio was 13-15 % showing typical values for Indonesian cocoa. The pH after fermentation was about 4.5, what is related to the high pulp quantity per seed. After fermentation acetic acid values of about 1.95 g/100 g dry matter confirmed low pH values of cocoa. The sucrose content was of <0.16 g/100 g dry matter of cocoa, signilizing good hydrolisation of the disaccharid after fermentation. The content ratio between fructose and glucose after fermentation was of 1.6:1, confirming good fermentation.

The drying behaviour and the quality changes of fermented cocoa was monitored by drying of 30 cm thicklayers of cocoa to a moisture content of 7 %. Thereby it was studied if two stage drying with different temperature regimes had an positive effect on cocoa quality. A laboratory dryer was used in order to simulate real drying conditions with a batch dryer. The trials consisted of two temperature series. First series comprised of predrying at 50 °C for ten hours, with subsequent increase to 60, 70 and 80 C at air velocity of 0.1 m/s. In order to compare sun drying with the implemented dying regimes, reference drying at 50 °C was included. The second drying series consisted of 50 °C drying for 25 hours, with subsequent rise to 60, 70 and 80 °C at air velocity of 0.1 m/s. During the second series, drying at 50 °C served as reference drying. Every four hours the drying bulk was vertical mixed to promote even distributed temperatures in the drying bulk and to enhance drying. Data from initial and final moisture contents, weight, bean temperature, temperature of the drying air and air velocity was collected, for monitoring the drying behaviour of cocoa. In order to monitor reducing sugars as main limiting factors for aroma formation, sugar concentrations were measured at the beginning and at the end of drying. For assessment of quality changes towards acetic acid contents, concentrations before and after drying were analysed. Quality in respect to sensorial evaluation and volatile compounds was carried out by the FRAUNHOFER INSTITUTE IVV FREISING.

For the assessment of sugar kinetics during the drying procedure, fermented cocoa was subjected to one step single layer drying with a drying oven. Cocoa was dried to a storable value of 7 %. The temperature regime consisted of drying at 50, 60, 70 and 80 °C. Every four hours samples were taken for extracting sugar and acetic acid concentrations and determining of moisture content. For monitoring the quality changes in respect to reducing sugars and acetic acid, standard enzymatic analyses were carried out in Indonesia and in Germany.

In order to apply the gained results trials with the Solar Processing Centre were carried out at the company area of COMEXTRA MAJORA. The drying trials consisted of two stage drying at 50 °C for 15 hours with subsequent rise to 70 °C and stationary drying at 70 °C. Vertikal mixing every four hours avoided cocoa clots formation and improved the volatilization of acetic acid. Samples for quality assessment towards reducing sugar and acetic acid cocentrations were taken at the end of the drying procedure. The dried cocoa was delivered to the warehouse of COMEXTRA MAJORA, where it was inspected by the company staff towards moisture content, mould, 100 bean weight and impurities. The stafff used for quality assessment a modified cut test.

The FRAUNHOFER-INSTITUTE IVV FREISING was comissioned with the sensory evaluation and analyses of volatile aroma compounds of dried cocoa beans, dried with the laboratory dryer and Solar Processing Centre.

Comparing the both "two stage drying" series in respect to the drying time, it was seen that the cocoa of the first series dried faster than the cocoa dried during the second series. The drying trials confirmed a negative correlation of the drying time to the drying temperature. Drying time of the first series was reduced by 15-20 % in comparison to the second series, due to the longer pre drying phase of 50 °C. During the drying trials glucose reduction was negativ correlated to all trial temperatures. Reductions in concentration of reducing sugars were stronger during the first series than during the second series. The decrease in content of reducing sugars, especially glucose is explained by reactions to Amadori compounds during the Maillard reaction or caramelization. Fructose showed more stability than glucose. It was observed that the reducing sugars cocentration was strong affected at 50/80 °C in both drying series. Drying air temperature regimes below 70 °C prooved to reduce far less reducing sugar concentrations. Best results in respect to reducing sugars were obtained during the second series, were glucose was reduced 20-30 % far less. It was prooved that a longer pre drying phase of 50 °C had little positive effects on acetic acid concentrations in comparison to first series. The higher the drying air temperatures were during the second phase of two stage drying the less acetic acid was volitzed. Acetic acid is impeded to volatize at high drying air temperatures due to fast hardening of the cocoa shell. No significant difference was found considering the acetic acid reduction and drying time between both drying series.

The results of the sugar kinetics showed that with increasing temperatures the glucose concentration is decreased stronger. Furthermore it was noted that reduction speed increased below moisture content of 30 %. At temperatures of 70 to 80 °C glucose content decreased by 82-93 %. In contrast drying at 50-60 % led to glucose reductions of 30 % to 62 % respectively. Fructose degrades slower at temperatures below 70 °C during two stage and single stage drying trials. At temperatures of 60 °C fructose faced during the first eight hours a short termed increase in content, in the end it was reduced by 10 % of initial value. Fructose experienced during 50 °C drying an total of increment 11 %. It has to be assumed that during 50 and 60 °C drying, residual sucrose was hydrolised being this the reason for the increments. Acetic acid content faced strong reductions at temperatures of 50 to 60 °C. At higher temperatures of 70 to 80 °C the acetic acid content was only reduced by 20 %. The acetic acid results during single stage drying reflect tendentially the concentrations of the two stage drying trials.

The results of the drying trials carried out with the SPC in Wotu/South Sulawesi led to similar glucose and fructose concentration values. Acetic acid concentrations of the two stage drying trial were higher than concentrations of the single stage drying. It was expected that two stage drying presented better results in respect to reducing sugars. This could not be prooved due to the fact that for the two stage drying trial unripe cocoa was supplied by the plantation. Drying time was reduced by 20 % at single stage drying. The locally carried out cut test led to very good results considering mould and 100 bean weight.

The sensory evaluation and aroma analyses carried out by the FRAUNHOFER INSTITUTE IVV FREISING led to best results at drying below 80 °C during two stage drying of the first and second series. Drying temperatures of 50/80 °C of both series led to an acidic to strange impression. The presence of furfurylic alcohol during the drying trials, evidences caramelization of reducing sugars during drying at temperatures above 60 °C. Besides the possibility of caramelization, the formation of Amadori compounds during Maillard reaction are confirmed by the aroma analyses. The drying trial with 50/80 °C of the second series presented beside the acid to strange impression, a strong "Maggi" taste. Sensory evaluation and aroma analyses of both SPC drying trials led to strange and musty off-flavours, due to the presence of ethyllactate and ethylacetate, which can be explained by defective fermentation.

The reducing sugar results of these research work lead to a recommendation of two stage drying with temperature regimes of 50/60 °C and 50/70 °C with predrying phases <10 hours. At 50/60 °C the content of reducing sugars was higher than drying at 50/70 °C. Nevertheless drying at 50/60 °C has a longer drying time and for implementing theses findings in practice 50/70 °C drying, is the most cost-effective. Acetic acid concentrations showed strong reductions at temperatures between 50-70 °C. Longer predrying phases showed no significant reduction in acetic acid content. In order to achieve a better understanding of the complex reactions of sugar kinetics during drying, it would be helpful to modell the sugar kinetics based on existing results. With the presented results a modelling approach could be started, but further research has to be done to get a reliable prediction from such a modell.