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Expression of cocoa butter from cocoa nibs

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Abstract

The effect of temperature (40–110 °C), applied mechanical pressure (20–80 MPa), applied pressure profile (constant/linearly increasing) and moisture content (0–8 wt.%, wet basis) on the expression of cocoa nibs were investigated. The maximum cocoa butter yield is achieved at 100 °C. The optimum moisture content with respect to cocoa butter yield is 1.3 wt.%. The cocoa butter yield increases with pressure up till 60 MPa where it has a value of 80% when dry cocoa beans are used. Neither the use of higher pressures nor the use of a linearly increasing pressure profile causes any further increases in the cocoa butter yield when the total pressing time is kept constant. The rate of expression increases with an increase in temperature or a decrease in moisture content. Higher cocoa butter yields (up to 89%) were achieved when cocoa liquor was pressed instead of cocoa nibs.

Keywords: Cocoa butter; Cocoa liquor; Cocoa nibs; Expression; Hydraulic filter press

1. Introduction

Cocoa butter is used in the manufacturing of chocolate, making it one of the most important ingredients used by the confectionery industry [1]. Since 1828, when Van Houten developed a press to partially defatten cocoa beans [2], mechanical pressing has been used to produce good quality cocoa butter from cocoa beans. Mechanical pressing can be done with either hydraulic presses or screw presses, but hydraulic filter presses are traditionally used for defattening cocoa beans. Mechanical pressing makes use of the unit operation expression, where the expressible liquid is expressed from a liquid-bearing mixture or matrix (in this case the cocoa nibs) by applying external pressure to deform and compress the mixture. Cocoa beans contain approximately 54 wt.% cocoa butter [2]. Usually the cocoa beans are cleaned, winnowed, roasted, alkalised and grinded to a fine paste known as cocoa liquor before being pressed.

In industry cocoa liquor is pumped into the press chamber at 1.5–2 MPa. Once the press chamber is filled the pressure is linearly increased to the required end pressure. The applied pressure is then kept constant for approximately 10 min before the filter cake is removed. Industrial hydraulic presses consists of twelve or more filter pots with an inner diameter of 425–600 mm [3], and invariably operates at temperatures of 90–110 °C to optimise the yield [2,4]. After pressing the cocoa liquor, the filter cakes are broken into smaller pieces, grinded and sold as cocoa powder. The taste and colour of cocoa powder does not depend on the fat content. Cocoa powders with lower fat contents are easier to handle and clump less. Cocoa butter is a more valuable raw material than cocoa powder, selling at a price approximately 2 times higher than that of cocoa powder [5]. The optimisation of the cocoa butter yield is therefore desirable.

Roasting and alkalisation are performed to obtain specific colour and flavour characteristics in the cocoa solids, and theoretically do not influence the taste, flavour or characteristics of the cocoa butter. The particle size of the cocoa powder is achieved during the liquor grinding. Any grinding performed after pressing only reduces the size of the compacted aggregates formed during pressing. Considerable savings are possible if cocoa nibs (broken, de-hulled cocoa bean cotyledons) are pressed instead of cocoa liquor, whereafter the cocoa filter cakes are grinded, alkalised and roasted to obtain the desired flavour and colour. Pressing cocoa nibs will also avoid some of the problems encountered with pressing ultra-fine cocoa liquor; especially the entrainment of solid particles into the cocoa butter stream, clogging of the filter medium and malfunctioning of the felt sealing rings used in the press chambers [6].

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Up to date very little research has been done on the expression of cocoa nibs. Gros et al. [7] only investigated the influence of roasting and alkalisation on the expression of cocoa butter from cocoa nibs at pressures between 9 and 11 MPa and temperatures of 90 and 100 °C. They removed 24% of the total cocoa butter content by pressing untreated nibs. Alkalisation, roasting and an increase in the pressing temperature all increased the yield. This is probably due to damage of the cell structure, which causes more of the cocoa butter to be freed from the cell structure.

Cocoa beans contain lipid components, and can therefore be defined as an oilseed. It is known that several factors influence the yield obtainable by pressing oleaginous seeds. Pre-treatment, temperature, pressure and moisture content are known to be the most important expression parameters [2,7–23]. The optimum temperature and moisture content is unique for each oilseed [9,12–17,20–25]. However, it is not only the oil yield, but also the rate at which this yield is achieved that determines the performance of an expression operation. The rate can be quantified with the consolidation ratio U_C, defined as:

$$U_C(t) = \frac{L(t) - L_0}{L_{final} - L_0} \quad (1)$$

where $L(t)$ is the filter cake thickness at time t, L_0 the initial filter cake thickness and L_{final} is the filter cake thickness at the end of pressing.

In this work the influence of the temperature, pressure, pressure profile and moisture content on the press behaviour of cocoa nibs is investigated. First, the default operational settings that should be used are determined, whereafter the parameters are varied one at a time. Furthermore, the press behaviour of cocoa nibs is compared to that of cocoa liquor. Both the yield (defined as the mass of cocoa butter removed as a percentage of the total mass of cocoa butter contained in the cocoa nibs) and the rate at which the yield is achieved are studied. The rate of pressing is only discussed in cases where it is significantly influenced by the parameter being studied.

2. Materials and methods

2.1. Experimental set-up

Fig. 1 shows the laboratory scale press with one drainage area constructed for this study. It consists of a hydraulic plunger (4) that can exert pressures of up to 100 MPa on the material and moves uni-axially in a cylinder with a diameter of 30 mm. The cocoa nibs are placed on top of a sieve plate (7) covered with a fine wire mesh acting as a filter medium (6). The filter medium is woven from 0.6 mm thick chromium steel (type 430) wires in a configuration of 13 bundles of three threads per 25.4 mm, with 212 wires per 25.4 mm perpendicular to these bundles. When cocoa liquor is pressed two layers of fast speed filter paper (No. 4 Whatman International Ltd., Maidstone, Kent, UK) are placed beneath the wire mesh. The filter medium is kept in place inside the sieve plate with a Teflon ring, which also prevents solids from being extruded into the collection chamber. The expressed cocoa butter is collected in the collection chamber (8) below the sieve plate. The press is fitted with two jackets (9) in which a heating medium can be circulated to enable isothermal operation (±1 °C) at elevated temperatures (30–100 °C). The hydraulic pressure is regulated electronically with a type SRX controller (RKC Instruments, Tokyo, Japan). The set points for the controller are set with the electronic interface SpecView Plus (SpecView Ltd., East Sussex, UK). The distance the plunger has advanced is continuously measured with a position transducer (2) (SPH-50, WayCon Positionsmesstechnik GmbH, Unterhaching, Germany) in order to determine the actual thickness of the filter cake (accuracy ± 0.01 mm). All data is recorded digitally with a memo-graph (Visual Data Manager, Endress & Hauser B.V., Naarden, The Netherlands) at a frequency of 1 Hz.

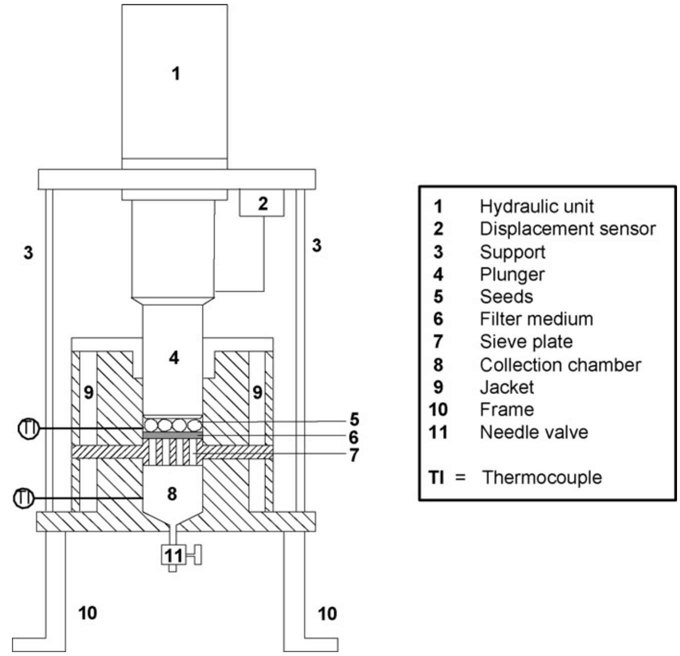

Fig. 1. Schematic depiction of the laboratory press (not to scale). (1) Hydraulic unit; (2) displacement sensor; (3) support; (4) plunger; (5) seeds; (6) filter medium; (7) sieve plate; (8) collection chamber; (9) jacket; (10) frame; (11) needle valve; (TI) thermocouple.

2.2. Experimental procedures

Unless stated otherwise, the cocoa nibs were dried at 103 ± 1 °C until completely dry to ensure that all press experiments were performed at the same moisture content. The influence of moisture content on the expression of cocoa nibs was also investigated. The desired mass of nibs was placed on top of the filter medium. The plunger was lowered to the level of the nibs after which the nibs were allowed to equilibrate for 30 min to the temperature of pressing (40–100 °C). The plunger exerted no pressure on the nibs during the time required for reaching thermal equilibrium.Pressing was performed directly after reaching thermal equilibrium by adjusting the hydraulic pressure exerted on the plunger to ensure that the desired mechanical pressure (20–80 MPa) was exerted on the nibs. Unless stated otherwise the mechanical pressure was increased in 2 s and then kept constant for 10 min. This pressing time was chosen to allow the