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Food Components Affecting the Oil Absorption and Crispness of Fried Batter

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Abstract: Frying batters are used to add value to a product by improving texture, flavour, weight and volume and reducing water loss during frying which, in turn, lessens oil absorption. The physical characteristics of fried batters were studied using model systems based on rice flours. Crispness was positively correlated with amylose content, while oil absorption was negatively correlated with amylose content. Addition of pregelatinised rice flour improved crispness but resulted in increased oil absorption because of the porous nature of the fried product. Amongst the proteins (egg yolk, gluten, skimmed milk, whey and ovalbumin) studied, ovalbumin was able to reduce oil absorption and improve the crispness of the fried batter. Addition of calcium chloride also reduced oil absorption and improved crispness, while a little oil reduced the oil content of the fried batter and improved its taste. Addition of ovalbumin, oil or calcium chloride beyond the optimal levels reduced crispness and increased oil absorption in a linear manner. Modified tapioca starch and diglyceride emulsifiers improved crispness but increased oil absorption. The amount of water added to the formulation affected the physical characteristics of the fried batter. The optimal formulation for a crisp frying batter with reasonably low oil absorption was an amylose/amylopectin ratio of about 18 : 67; with (g kg^{-1}) 850 pregelatinised rice flour; up to 150 modified tapioca starch; 30 ovalbumin; 1 calcium chloride; 20 oil; 20 emulsifier and a water/flour ratio of 2 : 1. © 1998 Society of Chemical Industry.

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Key words: rice; protein; starch; calcium; batter; oil uptake; crispness

INTRODUCTION

Many snacks and dishes all over the world use fried batter as a constituent. Fried batter is defined here as a flour–water mixture which is deep-fried in hot oil. Frying batters are used to add value to a product by improving texture, flavour, weight and volume. The batter coating apparently functions to reduce water loss during frying which, in turn, lessens oil absorption. Water loss and oil uptake decrease with increasing gel strength of the fried batter, and ingredients such as methyl cellulose are found to be more effective than cellulose in reducing oil uptake (Pinthus *et al* 1992, 1993). A linear relationship between oil uptake and water removal has been reported (Gamble *et al* 1987). The constituents in the flour also affect the characteristics of the batter. Moisture, protein content, amylose and amylopectin components correlate with the elasticity, linear expansion, oil absorption and crunchiness of fried crackers or keropok (Mohamed *et al* 1989). Fried dough of maximum crispness and minimum oil absorption were obtained from flour mixtures containing three parts rice flour for each part of glutinous rice flour with an amylose : amylopectin ratio of 9 : 78 (Mohamed and Hamid 1994). Batters and breadings influence oil absorption (Duxbury 1989) but reports have been inconsistent (Makinson *et al* 1987). Fried food can absorb up to 490 g oil kg^{-1} final product weight (Makinson *et al* 1987). Oil uptake is affected by many factors including oil quality, temperature, frying time,

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shape, composition, porosity, prefrying treatments, coating, moisture content and others (Smith *et al* 1985; Gamble and Rice 1988).

This study was conducted to investigate factors affecting the oil absorption and crispness of fried batters using model systems based on rice (*Oryza sativa*) flours. Factors studied include moisture, amylose/amylopectin content, various proteins, oil, emulsifiers, calcium, modified starches and the effect of pregelatinisation. This study will help in the formulation of mixtures for producing crispy, or low oil-absorbing fried starch-based batters.

MATERIALS AND METHODS

Rice flour (Maju Perak Rice Flour Co Ltd, Perak, Malaysia) was obtained from a local retail shop. Rice flours were mixed into batters by the addition of measured amounts of 16 g kg^{-1} salt solution until the viscosity was approximately 200 cP (measured with a Brookefield viscometer; Model: LPV Medium, Brookefield, USA). Fifteen millilitres of the batter was then spread over a flat circular stainless-steel mould and fried in RBD (refined, bleached and deodorised) palm olein for 15 ± 1 min at 185°C. The fried batter was drained and cooled. For effects of varying amylose/amylopectin content on batters, rice flour were replaced by 0, 100, 200, 300, 400 and 500 g of glutinous rice flour kg^{-1} (Cho Heng Rice Vermicelli Factory Co Ltd, Malaysia). The effects of pregelatinised flour and the addition of various concentrations of oil, calcium chloride, emulsifiers (gel form diglyceride emulsifier, Quick 75®), various proteins, modified tapioca starch (crosslinked using phosphorylating agents; CH20® from Meilun Food Chemicals Co Ltd, Malaysia) and water (1500, 1750, 2000, 2250, 2500, 2750 and 3000 g kg^{-1} rice flour) on the oil absorption and texture of the batters were determined. For effects of various proteins, 0–80 g of protein-rich materials kg^{-1} rice flour were added into the batter mix. The protein-rich materials studied were powdered chicken egg ovalbumin (A-5253, Sigma Chemical Co, St Louis, MO, USA), egg yolk (330 g kg^{-1} lipid, 480 g kg^{-1} water, 10 g kg^{-1} carbohydrate and 160 g kg^{-1} protein; from 1 day old eggs obtained from the University farm), skimmed milk powder (355 g kg^{-1} protein; Graduate Brand from F&N dairies, Malaysia), gluten (750 g kg^{-1} protein; Meilun Food Chemicals Co Ltd, Malaysia), and whey (120 g kg^{-1} protein; Damah Trading Co Ltd, Malaysia).

Pregelatinised flour was prepared using a drum drier (APV Mitchell Ltd, Model No 465/82) (3 bar steam pressure at 133·5°C; 0·1 mm gap; at 2 rpm) on the rice flour slurry (7 : 3, water/flour). This water/flour ratio was found to be optimal to produce a good homogeneous pregelatinised rice flour, which did not stick to the drum and did not harden on cooling. Protein and oil contents were determined using the micro-Kjeldahl (AOAC 1970, method 42·014) and the Soxhlet extraction methods (AOAC 1970, method 14·080), respectively.

Starch content was determined by hydrolysing the starch and determining the reducing sugar content (Osborne and Voogt 1978). Sugars were first removed from the starch using hot 80 : 20 ethanol/water. Excess protein and oil were then extracted for 1 h on a steam bath using alcoholic KOH (50 g kg^{-1} 950 g kg^{-1} ethanol). The extracted starch from 0·2 g of flour was gelatinised in 30 ml distilled water for about 3 h in a 100°C oven and 2·0 ml of this gelatinised starch solution were hydrolysed with 0·2 ml amyloglucosidase (82 units, from NOVO enzymes, Malaysia) in the presence of 2·0 ml, 0·1 M acetate buffer (pH 4·5) for 1 h at 55°C. The amount of glucose released was determined by the Nelson–Somogyi method and multiplied by a factor of 0·9 to give the total starch content in the sample (Southgate 1976). Amylose was determined by the reaction with $KI\text{-}I_2$ (Morrison and Laignelet 1983). The amylopectin content of the starch was calculated by difference and the amylopectin content of the whole flour can be calculated using the formula:

$$\text{amylopectin in flour (g kg}^{-1}) = \text{amylopectin in starch (g kg}^{-1}) \times \text{starch in flour g kg}^{-1})$$

Hardness was defined as the fracture force determined using a 8 mm diameter Magnus Taylor probe attached to the Instron Universal testing machine and a crosshead speed of 5 cm min^{-1}. Oil absorbed was determined by the difference in oil contents before and after frying as determined by Soxhlet extraction. All measurements were done on at least six samples.

Panel sensory evaluation was done on the fried batter by ten trained taste panelists on a 1–7 hedonic scale for crispness, oiliness, taste, appearance and overall acceptability (7 = like extremely). Data were statistically analysed by ANOVA for significant differences at the 5% level.

RESULTS AND DISCUSSION

Table 1 shows the amylose, amylopectin and protein composition of the flours under study.

Effect of amylose/amylopectin content on oil absorption and crispness of fried batter

Figure 1 shows that oil absorption increased linearly with increased amylopectin content in the starch ($r^2 = 0{\cdot}09$). Increasing the amylopectin content or reducing the amylose content also decreased the hardness of the fried batter ($r^2 = 0{\cdot}96$) to the point where it became soft and soggy. The addition of 50 g glutinous

TABLE 1
Composition (g kg^{-1}) of various starch flours used for making fried batters

Flour sample	*Amylose (g kg^{-1})*	*Amylopectin (g kg^{-1})*	*Protein in flour (g kg^{-1})*
Rice	179	669	56
Glutinous rice	11	791	63
Tapioca	170	740	10
Corn starch	220	650	05
Modified tapioca	164	700	08
Modified waxy corn	10	840	04
Commercial crispy batter flour (three varieties)	164–70	680	91–99

rice flour per kg batter was acceptable; above 50 g kg^{-1} the increased amylopectin content caused excessive uptake of water and the batter became a soft gel on cooking. Sensory evaluation scores showed that a hardness value of about 0·75 kg force was most desirable because it indicated that the fried batter was crispy and brittle, being neither too soft nor too hard. Hardness of the fried batters is most likely influenced by the degree of polysaccharide–polysaccharide, polysaccharide–water, polysaccharide–oil and polysaccharide–protein interaction. The ability of the branched amylopectin structure to hold and interact strongly with water resulted in a soft soggy batter. Increasing the amylose content would increase the polysaccharide–polysaccharide interaction, giving a more crunchy batter and reduced oil absorption. Too much amylose produced a fried product that was too hard/tough to chew. The optimal amylose/amylopectin ratio for production of good crispy frying batter was about 18 : 67.

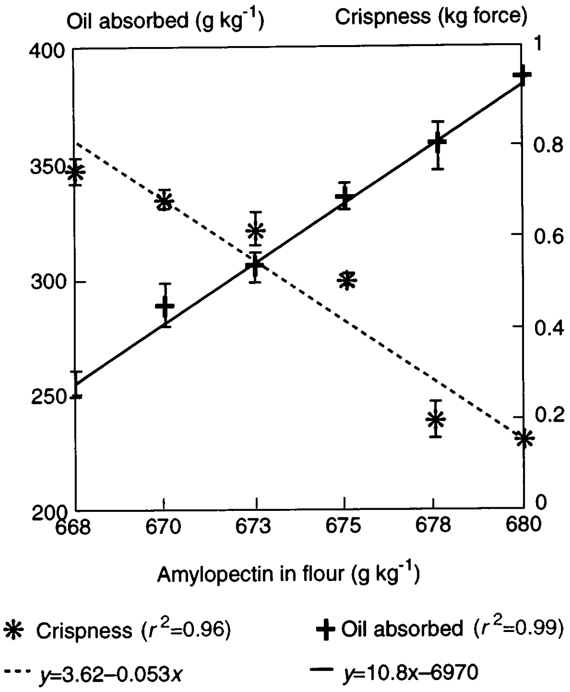

Fig 1. Effect of amylopectin/amylose on oil absorption and crispness of fried batter.

Effect of adding pregelatinised rice flour and pregelatinised glutinous rice flour on the crispness and oil absorption of fried batter

The use of pregelatinised rice flour resulted in a fried batter that was porous and consistent, giving a high crispness value, and even coating but also high oil absorption (Figs 2 and 3). In the presence of pregelatinised rice flour, more water was needed to get the required viscosity since the pregelatinised flour readily absorbed water. The moisture evaporated during frying, leaving pores that absorbed oil. Pregelatinised rice flour content correlated linearly with crispness and oil absorption ($r^2 = 0{\cdot}99$ and 0·98, respectively). The product that was most liked by the panelists was the mixture containing 850 g kg^{-1} pregelatinised rice flour.

Addition of even 20 g kg^{-1} pregelatinised glutinous rice flour increased oil absorption such that the fried batter became very oily. This is probably because of the reduction in amylose content which would otherwise help inhibit oil absorption. The fried batter had reduced crispness, was not cohesive, stuck to the mould, and tended to disintegrate on frying. The viscosity of the batter was high and three times as much water as in the normal formulation was required to get to the required viscosity. The batter was translucent and resulted in a soggy product. Addition of pregelatinised glutinous rice flour in the formulation was therefore unsuitable.

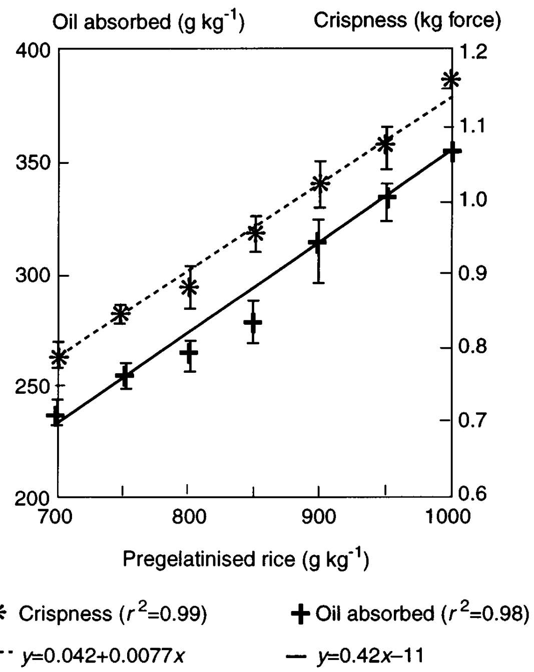

Fig 2. Effect of pregelatinised rice on oil absorption and crispness of fried batter.

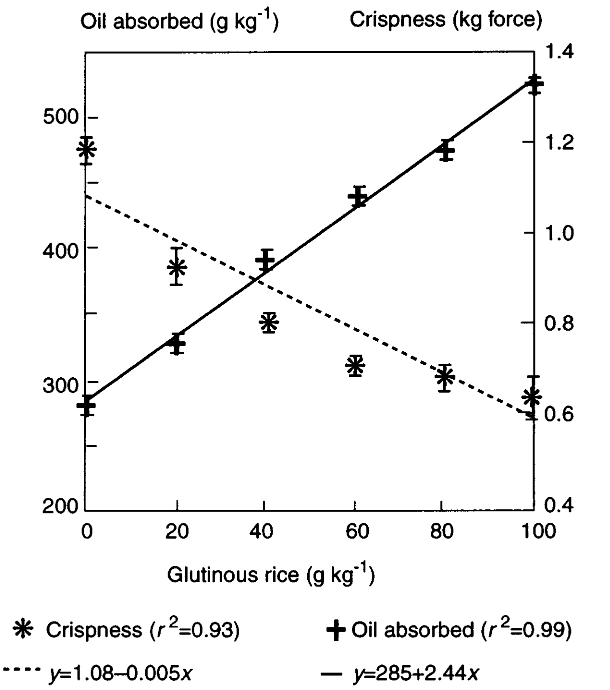

Fig 3. Effect of pregelatinised glutinous rice on oil absorption and crispness of fried batter.

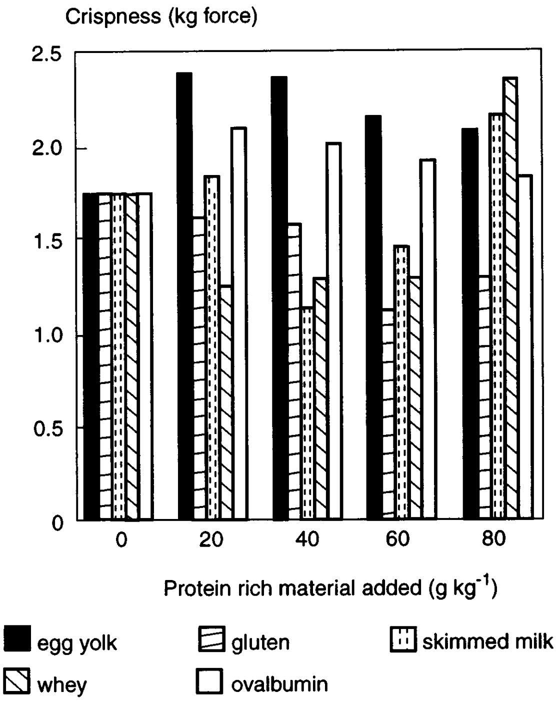

Fig 4. Effect of various proteins on the crispness of fried batters.

Effect of various proteins on the crispness and oil absorption of fried batter

Protein caused an increased rate of browning to the fried batter because more amine groups were present to participate in the Maillard reaction. Proteins can hydrate/hold water and possess emulsifying ability due to their hydrophilic and lipophilic side chains. Excess protein may reduce crispness and increase oil uptake by emulsifying more oil and water into the fried product. Addition of ovalbumin (optimum 20 g kg^{-1}) to the batter improved crispness and colour. Ovalbumin reduced oil-uptake of the fried product, probably because of its lipophobic nature (Kato and Nakai 1980). Reduced oil uptake has also been related to thermal gelation and the film-forming ability of non-protein substances (Anon 1987; Henderson 1988) and may well apply to some proteins. Gluten, milk and whey may affect texture by reducing polysaccharide–polysaccharide interaction. Addition of egg yolk increased both the oil absorption and hardness of the fried batter (Figs 4 and 5) probably because most of the proteins are in the form of lipoproteins (lipovitellins) and phosphoproteins (phosvitin) which can reduce the surface tension between oil and water and result in greater oil absorption (Parkinson 1966).

Effect of adding calcium with 30 g kg^{-1} ovalbumin on the crispness and oil absorption of fried batter

Addition of calcium improved crispness (Fig 6). Calcium may play a role in binding with pectin or proteins making them more brittle and may therefore interfere with starch–starch interactions. Calcium reacts with pectins to form insoluble calcium pectinate and pectate (Lindsay 1985). Calcium is also known to form Ca bridges with the acidic side chains of protein making them less soluble (Saio 1979; Lu *et al* 1980; Wang and Hesseltine 1982). A good correlation was found between calcium concentration and reduction in oil absorption or crispness (r^2 = 0·99 and 0·99, respectively). Addition

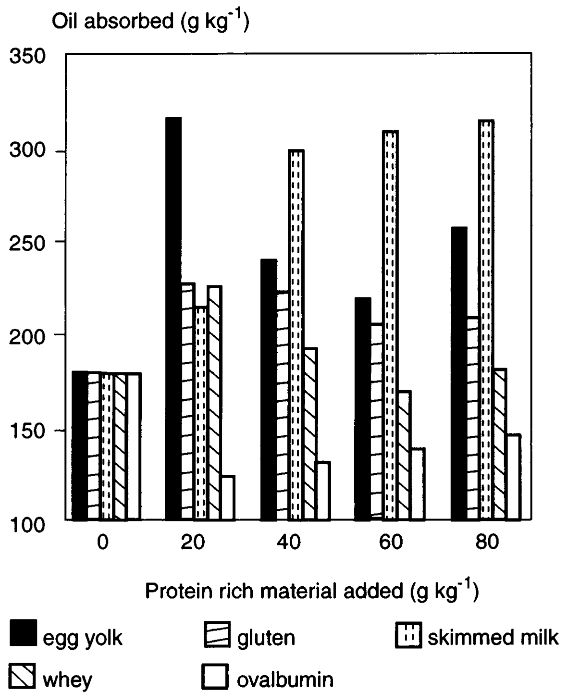

Fig 5. Effect of various proteins on the oil absorption of fried batters.

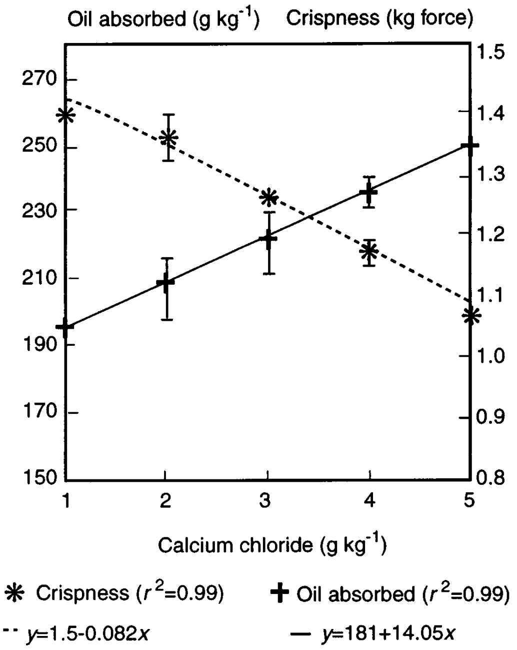

Fig 6. Effect of calcium chloride on oil absorption and crispness of fried batter.

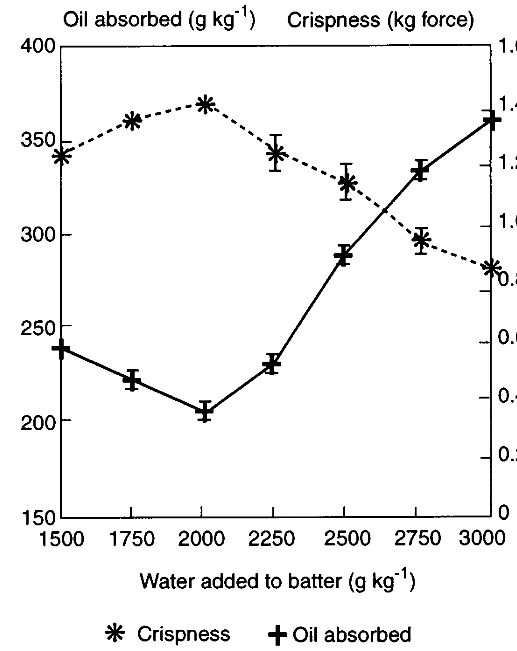

Fig 7. Effect of batter water on the oil absorption and crispness of fried batter.

of 1 g calcium chloride kg^{-1} batter decreased oil absorption but further addition increased the oil absorption of the fried batter. Because the pectin content in the flour is very small, only a little calcium is required. Excess calcium chloride adversely affects the taste (bitter) and changes the pH of the batter resulting in increased oil hydrolysis, formation of free fatty acids and short carbon chain products. All these occurrences would increase the polarity of the oil components and probably result in increased oil absorption into the batter.

Effect of water on the crispness and oil absorption of fried batter

The optimal water content for minimal oil absorption was 2 g g^{-1} flour mixture and this corresponded with the fried batter that had the highest fracture force (Fig 7). Increasing water content resulted in a thinner, less viscous batter which released a lot of moisture, resulting in a porous product which absorbs oil. Batters that were two thick were not able to coat the mould evenly. Initial and final moisture contents greatly affect oil uptake during deep-fat frying (Gamble and Rice 1988) and a linear relationship between oil uptake and water removal was reported by Gamble *et al* (1987).

Effect of adding emulsifiers and oil on the crispness and oil absorption of fried batter

Adding a little oil (20 g kg^{-1}) decreased the oil absorbed by the batter and improved the taste of the fried batter. Further increase in added oil increased the oil content of the fried batter linearly and did not overly change the crispness (Figs 8 and 9). Addition of oil facilitates the preparation of the batter by reducing the optimal mixing time to 4 min. Longer mixing time caused the batter to become viscous again probably because of a small degree of the starch swelling, hydrophobic interaction and/or slight denaturation of some protein.

Addition of emulsifier (20 g mono- and diglycerides kg^{-1}) improved crispness and reduced the force required to break the fried batter (from 1·7 kg to

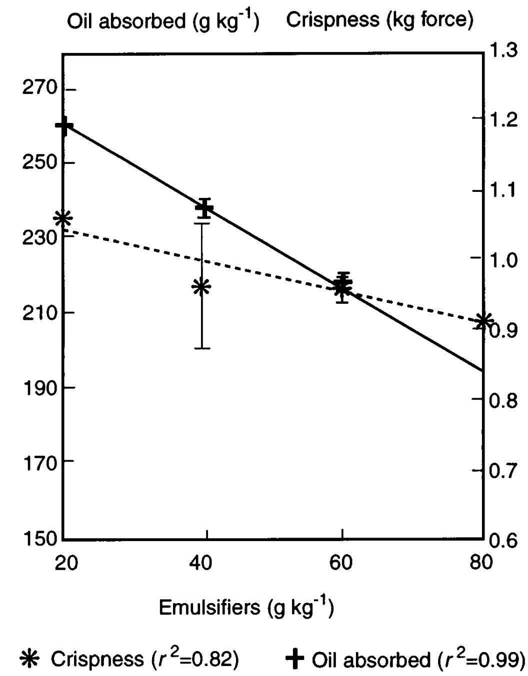

Fig 8. Effect of emulsifiers on oil absorption and crispness of fried batter.

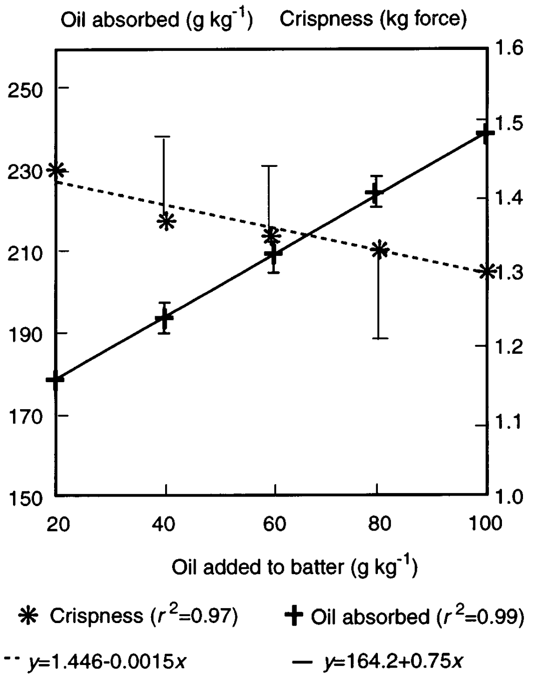

Fig 9. Effect of added oil in batter on oil absorption and crispness of fried batter.

~1 kg). Addition of up to 20 g emulsifier kg^{-1} increased oil absorption (from 180 g to 260 g kg^{-1}), but further increase caused a linear decrease in oil uptake ($r^2 = 0{\cdot}99$; $y = 28{\cdot}3 - 1{\cdot}1x$). Increasing oil and emulsifier concentrations in the batter decreased the batter's ability to stick to the mould even before frying.

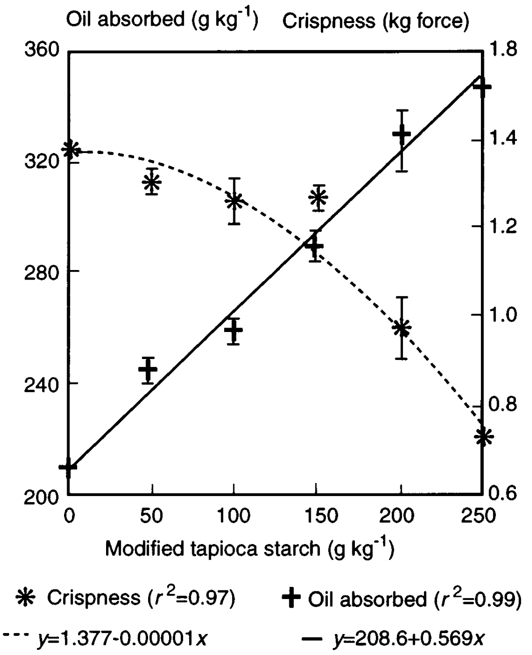

Fig 10. Effect of modified tapioca starch on oil absorption and crispness of fried batter.

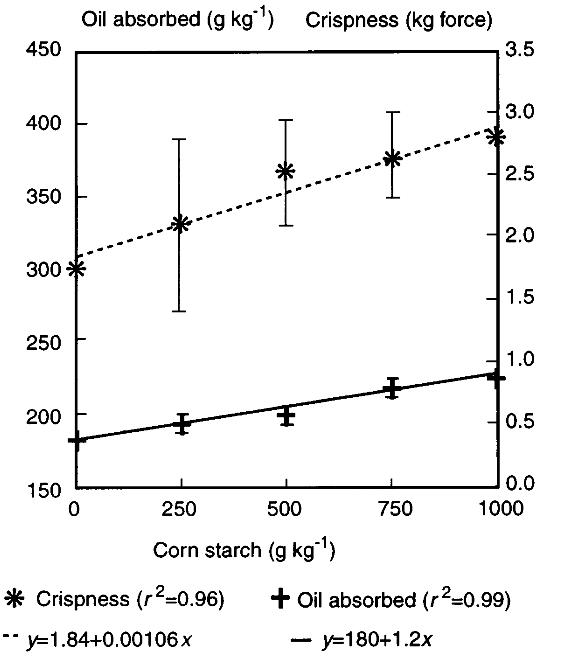

Fig 11. Effect of corn starch on oil absorption and crispness of fried batter.

Effect of different starches on oil absorption and crispness of fried batter

Oil absorption increased linearly with increased percentage of modified (cross-linked) tapioca starch in the rice flour batter, while crispness improved at an optimal concentration of 150 g modified tapioca starch kg^{-1} (Fig 10). Judging from the colour of the fried batter, addition of modified starch required the batter to be cooked 1–2 min longer because extra energy was needed to break the crosslinks in the modified starch granules. Addition of corn starch resulted in fried batters that were hard, with increased oil absorption (Fig 11) which is unsuitable in the formulation.

CONCLUSION

The components responsible for a crispy fried batter include an optimal amylose/amylopectin ratio of about 18 : 67; use of more than 85 g pregelatinised rice flour and up to 150 g modified tapioca starch kg^{-1}; 30 g ovalbumin; 1 g calcium chloride; 20 g oil and 20 g emulsifier kg^{-1}. The best water/flour ratio which gave optimal crispness and oil absorption for the formulation was 2 : 1.

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