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*Original article*

# Influence of ginger and banana starches on the mechanical and disintegration properties of chloroquine phosphate tablets

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**Abstract**

**Objective:** The influence of two experimental starches - ginger starch obtained from *Zingiber officinale* and banana starch from *Musa sapientum* - on the mechanical and disintegration properties of chloroquine tablets have been studied in comparison with the influence of official corn starch. **Methods:** Chloroquine tablets were formulated using various concentarions of the starches as binding agent. The mechanical properties of the tablets were assessed in terms of crushing strength and friability and the crushing strength-friability ratio (CSFR) while drug release properties were evaluated based on disintegration and the time of tablets. **Results:** The ranking for crushing strength and CSFR was corn > banana > ginger starch while the ranking was reverse for friability. The disintegration time increased with packing fraction and starch concentration in the rank order of formulations containing corn > banana > ginger starch. The CSFR/DT values increased with concentration of starch binder indicating an improved balance between binding and disintegrant properties of the starches. Statistical analysis showed that there were significant ($P<0.001$) difference in the CSFR/DT for tablets containing the various starch binders. **Conclusion:** The mechanical and disintegration properties of the experimental starches compared favorably with those of corn starch and ginger starch could be more useful when faster tablet disintegration is desired.

**Keywords:** Ginger starch; Banana starch; Corn starch; Binding agent; Mechanical properties; Disintegration time

## INTRODUCTION

Starch is one of the traditional and the most widely used excipients in the manufacture of solid dosage forms. Starches may be incorporated intragranularly as a granulating or binding agent in the form of mucilage or paste, or extragranularly to facilitate disintegration. When starch is wetted and converted into mucilages or pastes and added intragranularly, it loses most of its swelling propert[1,2] but may still effect tablet disintegration within acceptable limits[3] probably due to capillary action (wicking) of the starch, which is believed to depend on the porosity of the tablets[4].

In recent times, a lot of efforts have been expended in the development of starches obtained locally from different botanical sources as pharmaceutical excipents[5-9]. Starches that have been employed for these purposes include yam, sorghum, plantain, breadfruit and cassava[5-9]. With the versatility of starches in various solid dosage forms, there is the need to continue to develop new starch excipients with suitable properties to meet the special needs of drug formulators.

Ginger and banana are potential starch sources that have not been explored in pharmaceutical tablet formulations. Ginger starch is obtained from the rhizomes of *Zingiber officinale* Roscoe (Family Zingib-

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eraceae). Ginger is indigenous to Asia, but is cultivated in the West Indies, Africa, Java, and other tropical regions of Africa, Asia and America. Ginger starch is present as 30% - 40% dry weight of ginger rhizome and the amylose : amylopectin content was found to be 25:75[10]. Banana starch on the other hand, is obtained from the unripe peeled fruit of Musa sapientum Linn (Family Musaceae). The starch content of the unripe fruit ranges between 61% and 76.5%. The amylose:amylopectin content was found to be 19:81[11]. A literature search revealed that little work has been reported on the potentials of these starches as pharmaceutical excipients in tablet formulations. Thus in the present study, the influence of ginger and banana starches used as binding agents in chloroquine tablet formulations was evaluated in comparison with the effects of official corn starch. The mechanical and disintegration properties of the tablets were used as assessment parameters. Chloroquine phosphate, an important antimalarial drug, was chosen for the present work due to its poor compression properties, and therefore requires a binding agent among other excipients to form good quality tablets.

## MATERIALS AND METHODS

The materials used were chloroquine phosphate BP (Bayer AG, Leverkusen, Germany), lactose (DMV, Veghel, Netherlands), corn starch BP (BDH Chemicals Ltd., Poole, UK), ginger starch obtained locally from the rhizomes of *Zingiber officinale*, and banana from the unripe peeled fruit of *Musa sapientum*. The experimental starches were prepared in a University of Ibadan (Ibadan, Nigeria) laboratory. The description of the starches´ preparation and purification has been given elsewhere[9].

### Characterization of starches

*Determination of hydration capacity*

The hydration capacity was determined using the method of Ring[12]. 5ml of deionised water was added to 1g of starch and the suspension shaken for 5 minutes and then made up to 10ml with water and shaken intermittently for two hours and then left to stand for thirty minutes. The dispersion was centrifuged (Optima Centrifuge, Type BHG 500, Germany) for 10 minutes at 3,000rpm. The supernatant was discarded and the residue weighed ($W_1$). The residue was the dried at 70℃ to a constant weight ($W_2$) in a hot air oven. The hydration capacity was computed as x/y. Determinations were done in triplicates.

*Determination of swelling capacity*

The swelling capacity of the starches was determined using the method of Bowen and Vadino[13]. 5g of the starch was poured in a 100ml measuring cylinder ($V_1$), deionised water (90ml) added and the dispersion was shaken for 5 minutes and the made up to 100ml. The dispersion was allowed to stand for 24hours and the volume of the sediment measured ($V_2$). The swelling capacity was calculated as $V_2/V_1$. Determinations were done in triplicates.

### Preparation of granules

250g batches of a basic formulation of chloroquine (60% w/w), corn starch (10% w/w), and lactose (30% w/w) were dry-mixed for 5min in a planetary mixer (Kenwood Corp., Tokyo, Japan). The mixture was moistened with either 40ml of distilled water or the appropriate amounts of starch mucilage to produce granules containing various concentrations of the starch as binders. Starch mucilage was prepared by suspending the starch powder in distilled water; the aqueous slurry of the starch was then heated over a water bath with continous stirring until a mucilage was formed[9]. Massing was continued for 5min, and the wet masses granulated by passing them manually through a 12-mesh sieve (1 400 μm). The granules were dried in a hot-air oven for 18h at 50℃ and resieved through a number 16 mesh (1 000 μm). The granules were then stored in airtight containers. Particle densities were determined by the liquid pycnometer method with xylene as the displacement fluid.

### Preparation of tablets

Tablets (500 ± 100mg) were prepared from the 500-1 000m granules by compressing them for 1 minute with predetermined loads on a Carver hydraulic hand press (Model C, Carver Inc., Menomonee Falls, Wisconsin, U. S. A). Before each compression the 10.5 mm die and flat-faced punches were lubricated with a 2% w/v dispersion of magnesium stearate in ether : ethanol (1 : 1). After ejection, the tablets were stored over silica gel for 24 hours to allow for elastic recovery and hardening, and prevent falsely low yield values. Their weights (w) and dimensions

were then determined to within ±1mg and 0.01 mm respectively, and their packing fractions ($P_f$) were calculated using the equation:

$$P_f = w/V_t \cdot \rho_s$$

Where $V_t$ is the volume ($cm^3$) of the tablet and $\rho_s$ is the particle density ($g.cm^{-3}$) of the solid material.

### Crushing strength and friability tests

The crushing strengths of the tablets were determined at room temperature by diametral compression[9] using a Monsanto hardness tester (Monsanto, Cambridge, UK).

The percent friability of the tablets was determined using a friability test apparatus (Veego Scientific devices, Mumbai, Maharashtra, India) operated at 25rpm for 4 minutes.

### Disintegration tests

The disintegration times, DT, of the tablets was determined in distilled water at 37 ± 0.5℃ using a Manesty disintegration tester (Manesty Machines, Poole, UK). All measurements were made in quadruplicate, and the results given are the means of four determinations.

### Statistical analysis

Statistical analysis to compare the effects of the various starches on the mechanical and disintegration properties of chloroquine tablets was carried out using the Analysis of Variance (ANOVA) on a computer software GraphPad Prism® 4 (GraphPad Software Inc. San Diego, USA). Tukey-Kramer multiple comparison tests was used to compare the individual differences between the starches. At 95% confidence interval, *P* values less than or equal to 0.05 were considered significant.

## RESULTS

The swelling and water retention capacities of the starches are presented in Table 1. The ranking of both swelling capacity (SW) and hydration capacity (HC) capacities of the starches was ginger > banana > corn starch. The mean granule size (Ğ) of the chloroquine formulations are presented in Table 2. The mean granule size increased with increase in starch binder. The ranking for the mean granule size was formulation containing corn > banana > ginger starch. Representative plots of CS and F versus packing fraction for chloroquine tablets containing 5.0% w/w starch binder are presented in Figure. 1 and 2 respectively. The values of crushing strength increased while those of friability decreased with increase in the packing fraction of the tablets and concentration of starch binder. The values of CS, F and the CSFR for the tablets at packing fraction of 0.90 are presented in Table 2. The ranking for the crushing strength and CSFR of the tablets was corn > banana > ginger starch while the reverse was the case for friability. The disintegration time, DT was plotted against the packing fraction of the tablet and typical plots for tablets containing 5.0% w/w of starch binders are presented in Figure. 3. The disintegration time of the tablet at packing fraction of 0.90 are presented in Table 2. The disintegration time of chloroquine tablets generally increased with increase in the concentration of starch binder. The ranking for the disintegration time and the CSFR/DT ratio of the tablets was corn > banana > ginger starch.

**Table 1** The swelling and hydration capacities of the starches

| Starch | Swelling capacity ($V_2/V_1$) | Hydration capacity ($W_1/W_2$) |
|---|---|---|
| Banana | 1.62 | 1.83 |
| Ginger | 1.69 | 1.90 |
| Corn | 1.57 | 1.79 |

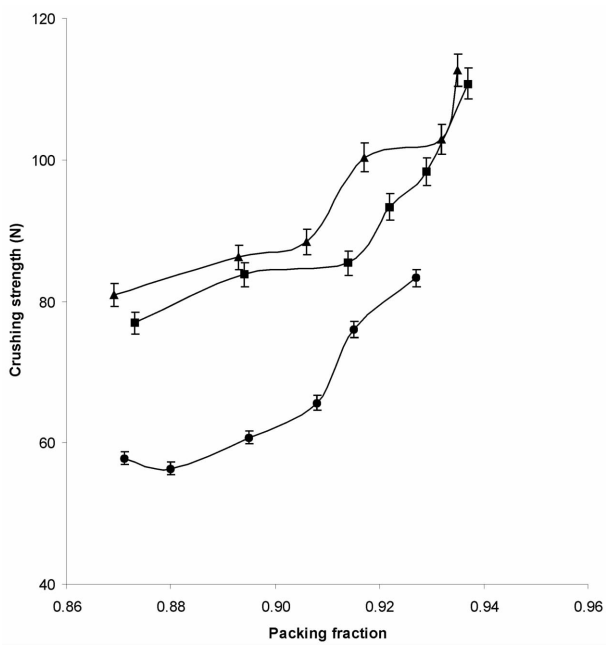


**Figure 1** Crushing strength (CS) versus packing fraction for chloroquine tablets containing 5.0% w/w starch binder (mean ± SD, $n=4$) ●, ginger; ■, banana; ▲, corn.

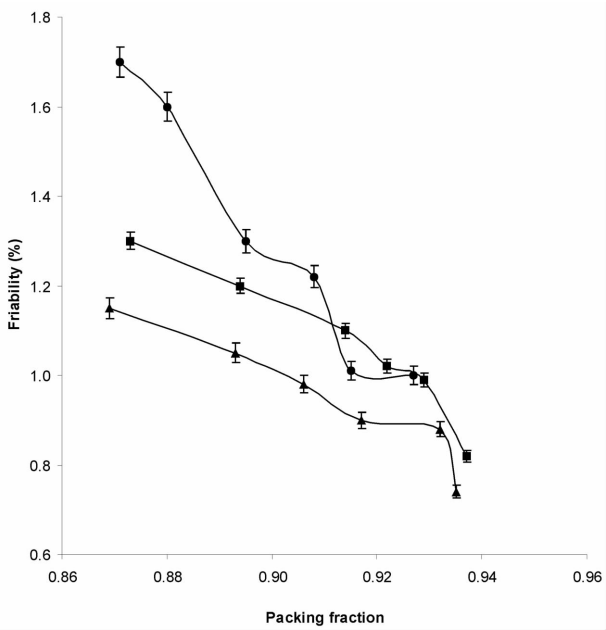


**Figure** 2 Friability (F) versus packing fraction for chloroquine tablets containing 5.0% w/w starch binder (mean ± SD, $n=4$) ●, ginger; ■, banana; ▲, corn.

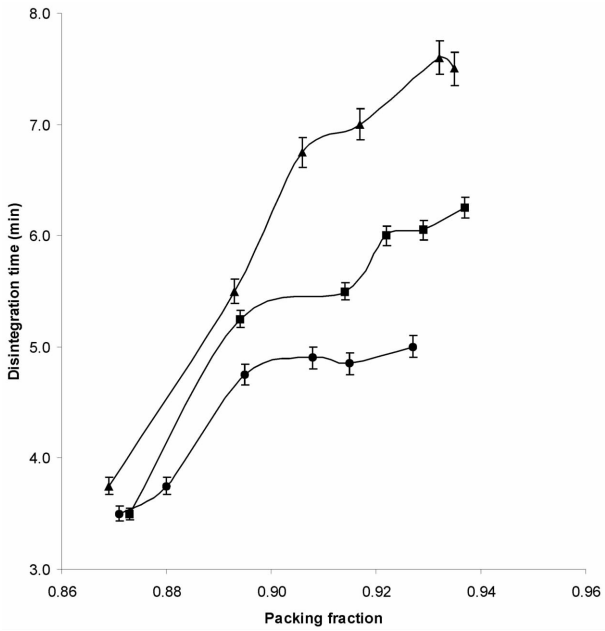


**Figure** 3 Disintegration time (min) versus packing fraction for chloroquine tablets containing 5.0% w/w starch binder (mean ± SD, $n=4$) ●, ginger; ■, banana; ▲, corn.

**Table** 2 Mean granule size and the mechanical and disintegration properties of chloroquine tablets at packing fraction = 0.90 (mean ± SD, $n=4$).

| Starch | Starch concentration (% w/w) | Mean granule size (μm) | Crushing strength (N) | Friability (%) | CSFR | Disintegration time (min) | CSFR/DT |
|---|---|---|---|---|---|---|---|
| Banana | 0.00 | 250 | 31.65 ± 0.98 | 3.43 ± 0.40 | 9.22 | 3.25 ± 1.20 | 2.84 |
| | 2.50 | 325 | 65.50 ± 1.58 | 1.28 ± 0.04 | 51.17 | 5.25 ± 1.80 | 9.75 |
| | 5.00 | 430 | 75.00 ± 0.50 | 1.18 ± 0.05 | 63.56 | 5.50 ± 2.20 | 11.56 |
| | 7.50 | 480 | 84.25 ± 1.11 | 0.89 ± 0.04 | 94.66 | 6.00 ± 1.20 | 15.78 |
| | 10.00 | 600 | 100.00 ± 0.40 | 0.81 ± 0.03 | 123.46 | 7.50 ± 1.60 | 16.46 |
| Ginger | 2.50 | 285 | 47.05 ± 0.60 | 1.81 ± 0.04 | 25.99 | 3.25 ± 0.98 | 8.00 |
| | 5.00 | 355 | 56.50 ± 0.50 | 1.27 ± 0.06 | 44.49 | 4.75 ± 0.10 | 9.37 |
| | 7.50 | 500 | 67.52 ± 1.03 | 0.93 ± 0.03 | 71.83 | 5.50 ± 0.90 | 13.06 |
| | 10.00 | 520 | 84.00 ± 0.50 | 0.83 ± 0.05 | 101.20 | 6.80 ± 0.40 | 14.88 |
| Corn | 2.50 | 340 | 73.00 ± 1.05 | 1.23 ± 0.02 | 59.35 | 5.50 ± 1.20 | 10.79 |
| | 5.00 | 500 | 85.50 ± 1.40 | 1.01 ± 0.03 | 84.65 | 6.50 ± 0.60 | 13.02 |
| | 7.50 | 580 | 92.00 ± 1.00 | 0.65 ± 0.04 | 141.54 | 8.00 ± 0.40 | 17.69 |
| | 10.00 | 665 | 114.00 ± 0.54 | 0.55 ± 0.02 | 207.27 | 10.00 ± 0.80 | 20.73 |

## DISCUSSION

The swelling capacity (SW) and hydration capacity (HC) of starch powders have been shown to be characteristic of the starch and have significant effects on their disintegrant properties[5]. Ginger starch exhibited the highest SW and HC while corn starch exhibited the lowest values. The result shows that the mean granule size, Ğ, increased with increase in the concentration of starch binder. This can be attributed to strengthening of bonds between particles as there would be more binder per bond as the concentration is increased. This observation agrees with the results obtained by other workers[14, 15]. Formulations containing corn starch exhibited the highest values of Ğ and those containing ginger starch the lowest values. Furthermore, statistical analysis shows that there were significant differences ($P<0.001$) in the Ğ for formulations containing the various starch binder.

The mechanical properties of chloroquine tablet formulations containing the starch binders were quantified by the crushing strength (CS), friability (F) of the tablets and the crushing strength-friability ratio (CSFR), which have been shown to be valuable in accessing the mechanical properties of pharmaceutical tablets[16]. The values of crushing strength increased while those of friability decreased with increase in the packing fraction of the tablets and concentration of starch binder. It is well known that a high concentration of plasto-elastic binding agent leads to an increase in plastic deformation of the formulation and subsequently to the formation of more solid bonds resulting in tablets with more resistance to fracture and abrasion[16]. The amount of bonds that would be formed would depend on the concentration of binder present[15]. Generally, the higher the CSFR values, the stronger the tablet. Tablets containing corn starch showed the highest CSFR while those containing ginger starch showed the lowest values. Statistical analysis using the Tukey Kramer multiple comparison test showed that there were generally significant ($P>0.01$) differences in the CSFR and friability values of the tablets containing the various starch binders.

The results of the disintegration test indicate that the disintegration time of chloroquine tablets generally increased with increase in the concentration of starch binder with tablets containing corn starch having the highest values and those containing ginger starch the lowest. Furthermore, all the tablets conformed to official requirements for uncoated tablets on disintegration i. e disintegration within 15 minutes. Thus, the starch binders facilitated extensive plastic deformation which would lead to increase in the area of contact between particles, reducing the rate of penetration of fluid into the interstitial void spaces. This results in the swelling of the disintegrant and disruption of the tablet is reduced at the higher packing fraction thereby prolonging the disintegration time of the tablets. This type of observation can be useful in selecting the starches as binder for tablets formulation. Statistical analysis showed that there were significant ($P<0.001$) differences in the disintegration time for tablets containing the various starch binders. Furthermore, ginger starch which showed highest HC and SW also showed the lowest disintegration time. Research have shown that starch binders added intragranularly may still effect tablet disintegration within acceptable limits probably due to capillary action (wicking) of the starch[3,4]. Thus, ginger starch could be more useful when faster tablet disintegration is desired.

The CSFR/DT ratio has been suggested as a better index of ensuring tablet quality because in addition to measuring tablet quality because in addition to measuring tablet strength (crushing strength) and weakness (friability), it simultaneously evaluates any negative effect of these parameters on disintegration[17,18]. In general, high values of CSFR/DT ratio indicate a better balance of binding and disintegration properties. The results indicate that the CSFR/DT values increased with increase in concentration of starch binder. Thereby indicating an improved balance between binding and disintegration properties of the starch as its concentration increased in the tablet formulations. Statistical analysis showed that there were significant ($P<0.001$) difference in the CSFR/DT for tablets containing the various starch binders.

## CONCLUSIONS

The results of the present work show that the experimental starches could be useful as binding agent in tablet formulations depending on the intended use of the tablets. The mechanical and disintegration properties of the experimental starches compared favorably with those of official corn starch. Furthermore, ginger starch could be more useful when faster tablet disintegration is of concern. The results suggest that the experimental starches could be developed as tablet excipient for commercial purposes.

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