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EVALUATION OF SOME STARCHES AS DISINTEGRANTS IN SODIUM SALICYLATE TABLET FORMULATIONS

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Abstract
The disintegrant properties of official maize and potato starches and locally produced cassava starch in sodium salicylate tablet formulations were studied. The disintegrants were added intragranularly in each batch. Concentration range of 5 % to 15 % w/w of each disintegrant was used. *In vitro* dissolution profile, uniformity of weight and content, disintegration time, friability and hardness tests were also evaluated. The mean disintegration times obtained at 5 % disintegrant concentrations were 32.33, 33.83, and 41.50 minutes for tablets formulated with maize, cassava and potato starches respectively. At 10 % w/w starch concentration, the mean disintegration times were 28.66, 34.67 and 32.33 minutes for maize, cassava and potato starches respectively, while at 15 % w/w, the results were 33.33, 46.67 and 42.67 minutes for maize, cassava and potato starches respectively. The T_{50} % obtained for all the batches of tablets produced indicates that all the disintegrants released up to 50 % of the active ingredient within 18 minutes for the range of concentrations investigated. The study showed that the starches tested performed relatively well as disintegrants in the order: maize > potato > cassava, with maize and potato being optimum at 10 % w/w while the locally produced cassava starch was optimum at 5 % w/w in the sodium salicylate tablet formulations.

Keywords: disintegrant properties, maize starch, potato starch, cassava starch, sodium salicylate tablets.

INTRODUCTION

Tablets have become the most frequently employed pharmaceutical dosage form in most areas of the world today. Compressed tablets have been defined as "…. solid dosage forms containing medicinal substances with or without suitable diluents, and they may be prepared by compression or by molding" (USP, 1980). This dosage form offers several advantages over other oral medication dosage forms, some of which are: (i) precision of dosage, (ii) durability of physical characteristics, for extended periods of storage and handling, (iii) stability of chemical and physiologic activity of the drugs, and (iv) convenience of administration (Lanchman *et al.*, 1986). Each tablet contains a known quantity of drug (active ingredient). A very important prerequisite of tablets for oral use is that when they are swallowed whole, they should readily disintegrate in the stomach. This property represents a great paradox in formulation, since tablets should be produced with sufficient strength to withstand the rigours of processing, coating and packaging, yet be capable of rapid breakdown when administered in order to release the drug rapidly.

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During the formulation and preparation of tablets, certain materials called disintegrating agents are incorporated to ensure disintegration in the gastrointestinal tract within the desired period. Starch is probably the oldest and most commonly used disintegrant in formulation of tablet dosage forms, usually at concentrations of 3 – 15 % w/w (Raymond *et al.*, 2003).

This work aims at evaluating comparatively, the disintegrating properties of two commonly used official starches, namely, maize and potato and a locally produced cassava starch as disintegrating agents in sodium salicylate tablet formulation.

MATERIALS AND METHODS

Materials

The following materials (chemicals and apparatus) were used as procured from the manufacturers: maize starch, acacia, lactose, **s**odium salicylate, magnesium stearate, potato starch (Merck), hydrochloric acid (CIV Co.), ferric chloride (M&B), cassava starch (The Nigerian Starch Mills Ltd., Ihiala, Nigeria), F-3 Single Punch Tabletting Machine (Manesty Ltd., Liverpool, England), oven (B&T Aseale Co.), torsion balance (White Elect. Inst. Co. Ltd.), Triple Beam Balance (OHAUS, U.S.A.), Erweka friabilator 20-40 min^{-1} (TAR 50234, W. Germany), Erweka hardness tester (TBH 28, Frankfurt, Germany), tablet disintegration test unit (TD 88 T 175, Manesty machines Ltd., Liverpool, 24, England), double beam balance (Gallenkamp, England), spectrophotometer (SP6-400 UV, Pye Unicam), hot plate with magnetic stirrer (Ruhramag), micrometer screw gauge (Mitutoy) and sieves (Jurgens & Co. Inst., W. Germany).

METHODS

Table 1 shows the formula used for preparing the various batches of sodium salicylate tablets using maize starch, potato starch and cassava starch respectively as disintegrants. Three batches were formulated for each disintegrant.

Preparation of tablets

Enough quantities of powdered ingredients were weighed using a beam balance. The formulae were stepped up to give enough tablets for evaluation tests. The wet granulation method was used for the tablet preparation. Each ingredient in the formula was reduced to very fine particle size using pestle and mortar. The weighed quantities of sodium salicylate, maize starch (5 % w/w) and lactose were blended thoroughly by triturating in a geometric manner in aliquot portions until homogenous fines were obtained. Mucilage of acacia (20 % w/v) was prepared by dissolving 6 mg of acacia powder in 30 mL of warm water and used to form a damp mass of the powder mixture. The damp mass was forced through a sieve of 1.70 mm aperture. The granules obtained were dried in a hot air oven at less than 60^0 C for about 15 to 20 minutes. The dried granules were re-screened by forcing gently through a 1.00 mm sieve. The granules were again screened through a 0.25 mm sieve and weight of fine and coarse granules obtained recorded. The fines obtained weighed between 15 and 19 % approximately. Just prior to compression, the total granules were lubricated with 1 % w/w of magnesium stearate by mixing in a powder bottle, first with the fines and then with the entire bulk of granules. The granules were compressed using the F-3 Single Punch tabletting machine. Tablets were made at the same machine compression pressure of 50 kgf. The machine die and punch were each time adjusted to give flat sodium salicyclate tablets of 300 mg weight and containing 100 mg of sodium salicylate per tablet.

The entire procedure was repeated using 10 % and 15 % w/w of maize starch, and also using 5 %, 10 % and granules formed was carefully

Table 1: Formula for preparation of the sodium salicylate tablets.

Ingredients	Concentration (mg)		
	Batch 1	Batch 2	Batch 3
Sodium salicylate	100.00	100.00	100.00
Disintegrant 5, 10 and 15 (% w /w) respectively	15.00	30.00	45.00
Acacia 20% w/w (2% w/w)	6.00	6.00	6.00
Magnesium stearate (1% w/w)	3.00	3.00	3.00
Lactose q.s to	300.00	300.00	300.00

Disintegrant = Maize, Potato and Cassava Starches respectively.

15 % w/w each of potato and cassava starches as the disintegrants. The tablets were then stored in air-tight containers for 24 hours for equilibration and their characteristics evaluated.

Powder standardization

Each of the disintegrants (maize starch, potato starch and cassava starch) was dried to a constant weight in a Manesty Oven at 60^{o} C before mixing with other ingredients. The powders were passed through a 200 mm sieve (4).

Granule characteristics

Flow rate and Angle of repose

A dry plastic funnel was placed in a ring, supported by a retort stand. A paper was placed below the funnel assembly on the bench and a sheet of fiber board placed below the funnel tip so that it fitted tightly, but loosely enough to be moved. Then the total weighed quantity of granules from one batch was transferred into the funnel. The fiber board was then drawn away and a timer was simultaneously started. The timer was stopped when all the granules had passed through the funnel and the time required for this, recorded. The height of the heap was measured using a ruler graduated in mm with a graph paper level. With a pencil, the contour of the base of the granule heap was outlined. The angle of the conical heap formed, (Ø) (Angle of repose), was then calculated from simple geometry:

$$\text{Tan } Ø = \frac{\text{Height of granule heap (mm)}}{\text{Radius of granule heap (mm)}} \quad \ldots\ldots (i)$$

Also the flow rate was calculated from

$$\text{Flow rate} = \frac{\text{Total granule weight (g)}}{\text{Time taken to flow out (sec)}}$$

The entire procedure was repeated in turn for the rest of the nine batches, repeating each time to get the average values.

Bulk and tapped densities

A weighed quantity of the total dried granules was placed in a suitable dry measuring cylinder of 100 mL capacity tilted to an angle of about 50^{o} while the granules were poured (Byrn, 1976; Erikson, 1964). The mean fluff bulk density (bulk density) Db, was calculated from:

$$Db = \frac{\text{weight of granules}}{\text{Bulk volume of granules.}}$$

The cylinder with content was then tapped uniformly on a flat firm surface until a constant volume was obtained.

The consolidated density (Tapped density) Dt, was calculated from: Dt = weight of granules/Tapped volume of granules. This procedure was repeated for the total granules of each of the nine batches. The Hausner quotient and percent compressibility were calculated for each batch from the equations:

$$\text{Hausner's Quotient, HQ} = \frac{Dt}{Db}$$

$$\% \text{ Compressibility} = \frac{(I - Vt)X \quad 100}{Vb}$$

Where Vt = Tapped volume; Vb = Bulk volume

Evaluation of tablet characteristics

All the tests, except some in-line tests, were initiated at least 24 hours after compression to allow for equilibration of tablets. All the evaluation tests were done and repeated for all of the nine batches produced and mean values calculated.

Uniformity of weight

The BP (1988) method was adopted. Twenty tablets were randomly selected from each batch and weighed individually to the nearest 0.1 mg using the Torsion balance, and then weighed together using the Beam balance. The mean tablet weight, individual deviations from the mean and per cent coefficient of variation were calculated.

Content of active ingredients (Absolute drug content)

Beer-Lambert's plot

The Beer-Lamberts calibration plot for sodium salicylate was first determined as follows:

A 100 mg % w/v solution of sodium salicylate was prepared in 0.1 N HCl. Dilutions of this solution were made by pipetting out 2 mL, 4 mL, 6 mL, 8 mL and 10 mL respectively into 100 mL measuring flasks, adding 5 drops of ferric chloride to each and making up to 100 ml with 0.1 N HCl. The absorbance for each of the diluted solutions was measured using SP6 – 400 UV spectrophotometer (Pye Unicam) and 0.1 N HCl as blank solution. The average absorbances were then plotted against the respective concentrations of the dilute solutions which gave a straight line passing through the origin (Beer's plot) with slope, 0.07 /mg%.

For the content of active ingredient test, ten tablets were selected randomly from each batch, crushed to powder in a mortar with pestle and an amount equivalent to the mean tablet weight was weighed out and dissolved in 100 mL of 0.1 N HCl solution. A 1 mL quantity of this solution was pipetted out into a 100 mL measuring flask. Five (5) drops of 5 % ferric chloride ($FeCl_3$) solution were added and the volume made up to 100 mL with 0.1 N HCl. The same process was repeated for all the batches. The absorbances of the resulting solutions were read after the colour development using a colorimeter (SP6 – 400 UV spectrophotometer, Pye Unicam) and 0.1 N HCl as blank solution. The average absorbances were determined and hence concentration using the Beer – Lambert's plot.

Hardness test

An electronic hardness tester (TBH 28, Erweka Frankfurt, Germany) was used. Ten tablets from each batch were tested individually for hardness. The mean hardness, variance, standard deviation and per cent coefficient of variation were calculated for each of the nine batches.

Friability test

The Erweka electronic friabilator (model TAR) was used for the test. Ten tablets were randomly selected

from each batch, gently brushed and blown free from adhering dust, and then used to carry out the test according to the procedure reported by Pietra and Setnikar (1970). The ten tablets were weighed together and placed in the revolving circular arm of the machine. The percentage loss in weight which occurred after 100 revolutions (i.e., after 4 minutes of 25 revolutions per minute) was taken as a measure of friability. This was repeated twice for all the batches.

Uniformity of diameter

The diameters of the tablets were measured using a micrometer screw gauge of 0.001 mm sensitivity. Ten tablets were randomly selected from each batch and used for the test. The mean diameter, variance, standard deviation and per cent coefficient of variation were calculated for each batch.

Uniformity of thickness

The thicknesses of the tablets were also measured with a micrometer screw gauge of 0.001 mm sensitivity. Ten tablets per batch selected at random were used for the test and the mean thickness, variance, standard deviation and per cent coefficient of variation were calculated.

Disintegration time test

The USP (1980) method was adopted using a Manesty tablet disintegration test unit (Model TD 88 T 175, Manesty Ltd., Liverpool, 24. England). The disintegration medium, 0.1 N HCl solution, was poured into each of the six 250 mL beakers of the equipment and the temperature of the surrounding water bath in a large beaker was maintained at 37.0 ± 1^0 C throughout the test by means of a heater. Six tablets were selected at random from a batch and each placed in each of the six baskets. The motor and the timer were simultaneously switched on. At the end of disintegration, when the last tablet particle passed through the screen, the time taken for each tablet was read and recorded. The process was repeated for all the batches and the mean time for each batch was calculated.

Dissolution rate test

The USP (1980) method was adopted. The dissolution medium (500 mL of 0. 1 N HCl) was poured into a 600 mL beaker into which a magnetic stirrer was placed and warmed to a constant temperature of 37 ± 0.5^o C on hot plate. One tablet per batch was placed in the basket which was dipped into the dissolution medium constantly stirred by the magnetic stirrer. With a pipette, 5 mL samples were withdrawn at the following time intervals: 1, 2, 4, 8, 12, 24, 30, 36, 42, 50 and 60 minutes for the first batch. For subsequent batches, samples were withdrawn at same intervals up to 42 minutes. The volume of samples removed was each time replaced with equal volume of the dissolution medium. The samples were diluted and analyzed for salicylic acid content after the colour development with 5 drops of 5 % ferric chloride solution. The absorbance was read on a colorimeter (SP6 – 400 UV Spectrophotometer, Pye Unicam). This was repeated twice for each batch and the mean absorbance for each sample determined. The concentrations were calculated with reference to the Beer's plot.

The per cent concentrations released and dissolution efficiencies were calculated from the following equations:-

% Concentration = Conc.releasedX100

Absolute drug content

Dissolution Efficiencies (DE) (%) at 24 minutes were calculated from the plots of per cent release against time as follows:

$$DE\ (\%) = \frac{\text{Area under the curve up to 24 mins}}{\text{Entire Area under the Curve}} \times \frac{100}{1}$$

$$= \frac{h/2\ (y_o + 2_{y1} + 2_{y2} + 2_{y3} + \ldots..2_{yn})}{\text{Length x Width}}$$

Where y = individual % concentrations.

$h = \frac{b - a}{n}$

b = last sampling time = 24

a = first sampling time = 1

n = number of samples = 7

Shaded areas under the curves were calculated from the Trapezoidal Rule (8) which says:

To approximate $\int f(x)\,dx$,

Use $T = h/2\ (y_o + 2_{y1} + 2_{y2} + \ldots.2yn\text{-}1 + y_n)$

For n intervals of length h

$= [\ (b\text{-}a)/n].$

Data Analysis

The data obtained were analyzed using ANOVA principles.

RESULTS AND DISCUSSION

GRANULE CHARACTERISTICS

Flow rate and Angle of repose

Table 2 shows a summary of various physical characteristics of the granule batches produced. The results show that all the granules have approximately similar flow rates of between 7 and 8 g/sec and angles of repose that range from 26^o to 33.7^o. According to Carter (1986), the value of this angle is high if cohesive and other forces are high and vice versa. In general, if the angle exceeds 50^o (5/18 π rad.), the powder will not flow satisfactorily while materials having values near the minimum, circa 25^o (5/36 π rad.), flow easily and well. This implies that the granules produced for all the batches would flow well, in the order cassava > maize > potato, from the hopper feed into the die cavity resulting in production of tablets of approximately uniform weights and contents. It has been stated that maize starch is cohesive and has poor flow characters (Raymond *et al.*, 1978).

The amount of fines in the granules lies approximately within 15 % to 19 % of the total granules per batch which is within acceptable limits.

Bulk and tapped densities

As shown in Table 1, the fluff bulk densities for the granules produced with maize starch (0.44, 0.50 and 0.49 g/mL for 5 %, 10 % and 15 % w/w) and potato starch (0.49, 0.48 and 0.46 g/mL for 5 %, 10 % and 15 % w/w) were approximately close while those for cassava starch (0.54, 0.53 and 0.51 g/mL for 5 %, 10 % and 15 % w/w) were slightly higher. Official compendia specified that the bulk and tapped densities for maize starch are 0.462 and o.658 g/cm^3 respectively (Raymond *et al.*, 1978). The bulk density of a powder or granules measures its packing behaviour. An increase in the consolidated bulk density is advantageous in tabletting as the fill volume of the die used would be reduced (Staniforth, 1984). It was also observed that tapped densities for the formulations were of the following order of magnitude: 5 % and 10 % cassava starch > 15 % and 10 % maize starch > 10 % and 5 % potato starch > 5 % maize starch, 15 % potato starch

and 15 % cassava starch. The consolidated (tapped) bulk density is indicative of the extent to which the different bulks are loosely packed. Batches containing both maize and potato starches had approximately similar values for fluff bulk density which agrees with earlier work by Okorie (1991). Cassava starch however, had slightly increased value. The implication is that the cassava starch has a less compact packing arrangement and is therefore more likely to allow faster penetration of moisture and cause faster release of the active ingredient in dissolution medium than maize and potato starches. All the granules produced have their Hausner quotients (HQ) lying between 1.18 and 1.45 with most having 1.3 approximately. Their per cent compressibilities lie between 16.13 % and 30.11 %. Hausner's quotient and Carr's compressibility have been used by many workers (Guyot-Herman and Lebiane, 1985; Lessen and Mattocks, 1958; Cartenson *et al.*, 1966) to predict the flow behaviour of powdered solids. The HQ is a measure of interparticulate friction and values of approximately 1.2 indicate good flowability (Aulton, 1988; Lessen and Mattocks, 1958) whereas more cohesive, less free-flowing powders such as flakes have HQ greater than 1.6 (Aulton, 1988). According to Carr, materials that have values of 5 – 15 %, 12 – 16 % and 18 – 21 % would possibly have excellent, good and fair flow behaviours respectively, while values of 23 – 35 % compressibility indicate poor flow. Carr's per cent compressibility of 35 – 38 is indicative of very poor flow properties and values greater than 40 % show extremely poor flow characteristics (Aulton, 1988). Therefore all the granules produced would generally have fair flow properties.

TABLET CHARACTERISTICS

Uniformity of weight

All the tablets complied with the BP requirements for uniformity of weight except for the batch formulated with 15 % maize starch where more than two (four) of the 20 tablets tested deviated by more than + 5 %. The results obtained agree with other reports on uniformity of weight (Saunders and Flemings, 1957).

Content of active ingredient

All the nine batches produced were formulated to contain 100 mg of sodium salicylate per tablet. The results complied with the BP and USP specifications for the content of active ingredient (BP, 1980). The preparations were therefore good and could be used for further tests.

Tablet hardness

A minimum mean hardness of 4.62 N was recorded for the batch containing 15 % w/w potato starch and a maximum mean hardness of 9.15 N was obtained for the batch containing 10 % cassava starch. The batch with 15 % cassava starch had mean hardness of 5.18 N, while other batches had values between 8 and 9 N. There were not much variations within a particular batch for the tablets tested. The result indicates that the tablets produced were hard enough to withstand breakage, chipping or crumbling during handling or transportation.

Tablet friability

It was observed that tablets from the batches formulated with 5 % w/w of both maize starch and potato starch respectively, 10 % w/w of both maize and cassava starches respectively and 15 % w/w cassava starch gave friability values far below 0.8 %. This indicates that these tablets would be

much less susceptible to abrasion and loss of particles from their surfaces during handling from the manufacturers to the consumers. Tablets from the batches formulated with 5 % cassava starch, 10 % potato starch and 15 % of both maize and potato starches respectively, however, gave values above 0.8 % indicating greater tendency towards abrasion and loss of particles, hence weight and drug content, during handling, since the binder concentration was constant in all the batches. However, all the tablets tested were strong enough that no capping or clear chipping occurred. Those with 15 % potato starch had the highest while batches with 10 % maize starch and 15 % cassava starch had negligible friability.

Uniformity of tablet diameter and thickness

All the tablets tested had similar diameter and thickness. The batches complied with the BP requirements for uniformity of diameter for non-coated tablets. The uniformity of thickness indicates problem-free flow through the feeder and proper deposition of granulation in the die during compression, resulting to uniform hardness per batch as same compression pressure was used.

Disintegration time

Table 3 shows the mean disintegration times obtained for different disintegrant concentrations. Figure 1 also illustrates the relationship between the mean disintegration times obtained and the various disintegrant concentrations.

Although none of the tablets tested complied with the BP general requirement of within 15 minutes for uncoated tablets (BP, 1973) while most of the batches nearly complied with the USP requirement of within 30 minutes (USP, 1980), some interesting comparison could be made from the results. The shortest disintegration time obtained was 28.66 minutes for 10 % w/w maize starch while the longest was 46.67 minutes for 15 % w/w cassava starch. The high compression pressure of 50 Kgf used was likely one of the reasons for the high disintegration times obtained. Rawlins (1984) had reported a disintegration time of 38.3 minutes with 1 % lubricant (Magnesium stearate) at compression pressure of approximately 1300 kg/cm^2.

At concentration of 5 % w/w, maize starch had the least mean disintegration time of 32.33 minutes followed by cassava starch with a time of 33.83 minutes and then potato starch with a time of 41.50 minutes. At 10 % w/w, the order was maize starch 28.66 minutes < potato starch 32.33 minutes < cassava starch 34.67 minutes. Similarly, at concentration of 15 % w/w, the mean disintegration times were: maize starch, 33.33 < potato starch, 42.67 < cassava starch 46.67 minutes. It could be seen that at any particular concentration (for the range evaluated), maize starch performed best followed by potato starch (except at 5 % w/w).

For a particular disintegrant, the disintegration time increased progressively with increase in concentration. For both potato and maize starches, the time decreased at 10 % concentration, then increased at 15 %. This interestingly shows that maize and potato starches as disintegrants, performed best at concentrations of 10 % w/w in this work. However, 5 % w/w of cassava starch performed better than 5 % potato starch. These observations agree with the reports of earlier workers (Sprengler and Schenker, 1937; Chalabala and Maly, 1966; Khar and Rhode, 1971). It was reported that when starches, effervescent combinations, gums and cellulose derivatives were compared in tablets of various drugs, the starches were generally better (Sprengler and Schenker, 1937). Corn (maize), potato

and wheat starches had the maximum effect at 10 % concentration, and rice starch had the maximum effect at 20 % concentration (Chalabala and Maly, 1966). Khar and Rhodes (1971) on comparative evaluation of five disintegrants incorporated in low solubility base (calcium sulphate dihydrate) and a high solubility base (lactose), found that corn (maize) starch was most effective at a concentration of 10 %. Maize starch was also shown to be most effective in wet granulation system as well as in soluble base, and was found to be very ineffective in the insoluble base.

The primary purpose of a disintegrant is to cause rapid breakup of the tablet into granules with a resultant increase in surface area thereby promoting rapid release of the active ingredient. Starch consists of amylose (about 20 %) and amylopectin (about 80 %) (Masahiro *et al.*, 2004) with the more common starches usually containing 20 – 25 % amylose and 75 – 80 % amylopectin while the waxy starches consist of almost pure amylopectin and less than 1 % amylose (Kunle, 2002). It acts as a disintegrant by swelling in the presence of water to burst open the tablet. Swelling property of starch is a function of the amylopectin constituent whose crystalline molecular chains are dissociated by hydration during the gelatinization of starch granules during the heating process (Masahiro *et al.*, 2004). Thus it appears that the maize starch had amylopectin content > potato starch > cassava starch, hence swole faster in the warm simulated gastrointestinal fluid (SGF) causing faster disintegration of the tablets in that order. This inherent property of the starch disintegrants and several other factors such as the manufacturing process and the effects of the binder and other excipients used certainly affected the results obtained.

Hance in 1902 claimed that the manufacturing process affects disintegration and that no one method is good for all tablets. Kavarana and Burlage (Kavarana. and Burglage, 1955) listed the factors that influence disintegration as: - tablet hardness, speed of compression, nature of lubricant and binder used, granulation process, and per cent moisture and dryness of disintegrating agents. Disintegration time could have been increased by increased compression pressure and tablet hardness.

Acacia gum powder was used as binder in formulation of the tablets. Gum-type binders may form a gel barrier around the tablet to inhibit disintegration and if the binder concentration is sufficiently large, delayed drug release is obtained (Huber *et al.*, 1966). The method of incorporating the disintegrants, that is, whether intra or extra-granularly, could also affect disintegration. Some workers (Sprengler and Jud, 1943; Kolarski and Krowezynski, 1970; Krowenzyski *et al.*, 1968) had reported that the addition of starches or colloidal silicon dioxide to granules (intragranularly) is more effective. The addition of starch before and after granulation has been described as most effective (Krebs, 1960).

Finally, it can be said that for each of the disintegrants evaluated, disintegration was generally fair at 5 % w/w, maximum at 10 % w/w and poor at 15 % w/w concentration. In fact, the concentration of 15 % w/w could be said to be too high to be employed for these disintegrants, one reason being that as starches, they could even impart some binding effects at very high concentrations in the wet granulation process.

Dissolution profile

Figures 2 - 4 show the effects of the different disintegrant concentrations on the dissolution profile of the sodium salicylate tablets. Table 4 shows the per cent concentration of active ingredient released at those time intervals. The effects were compared

Table 2: Summary of Granule Characteristics

Per Batch Disintegrant Conc. (% w/w)	Total Granules Mass (g)	Per Cent Fines %	Mean Flow Rate (g /sec)	Angle of Repose (degrees)	Bulk Density Db.	Tapped Density Dt (g/ml)	Hausner's Quotient Hg.	% Compressibility
MAIZE STARCH:								
5.00	19.50	17.95	7.43	26.00	0.44	0.61	1.39	27.27
10.00	23.90	16.74	8.00	27.55	0.50	0.68	1.36	27.08
15.00	23.00	19.57	8.00	28.35	0.49	0.71	1.45	30.11
POTATO STARCH:								
5.00	19.70	17.26	8.76	33.65	0.49	0.63	1.29	21.25
10.00	21.00	15.71	8.00	31.53	0.48	0.64	1.33	24.14
15.00	20.50	16.59	7.45	28.80	0.46	0.61	1.33	24.38
CASSAVA STARCH:								
5.00	23.80	15.55	7.93	27.14	0.54	0.74	1.37	27.27
10.00	26.40	19.70	7.04	27.64	0.53	0.73	1.38	28.00
15.00	23.50	15.32	7.83	26.85	0.51	0.60	1.18	16.13

Table 2(i): Granules Characteristics

Per Batch Disintegrant Conc. (% w/w)	Total Granules (Mass (g)	Mass of Fines (g)	Mean Flow Time (Sec)	Height of Granule Heap (mm)	Radius of Granule Heap (mm)	Bulk Volume (ml)	Tapped Volume (ml)
MAIZE STARCH:							
5.00	19.50	3.60	2.63	20.00	41.00	44.00	32.00
10.00	23.90	4.00	3.00	20.05	38.00	48.00	35.00
15.00	23.00	4.50	2.88	20.00	37.00	46.50	32.50
POTATO STARCH:							
5.00	19.70	3.40	2.25	24.00	36.00	40.00	31.50
10.00	21.00	3.30	2.63	23.00	37.50	43.50	33.00
15.00	20.50	3.40	2.75	22.00	40.00	44.30	33.50
CASSAVA STARCH:							
5.00	23.80	3.70	3.00	20.00	39.00	44.00	32.00
10.00	26.40	5.20	3.75	22.00	42.00	50.00	36.00
15.00	23.50	3.60	3.00	20.00	39.50	46.50	39.00

Table 3: Mean Disintegration Time (Mins) (± Standard Deviation).

DISINTEGRANT	DINSINTEGRATION TIME (MINS)		
	5% W/W Disintegrant	10% W/W Disintegrant	15% W/W Disintegrant
Maize Starch	32.33 ± 2.81	28.66 ± 1.80	33.33 ± 4.68
Potato Starch	41.50 ± 2.22	32.33 ± 3.21	42.67 ± 0.94
Cassava Starch	33.83 ± 3.44	34.67 ± 1.12	46.67 ± 1.37

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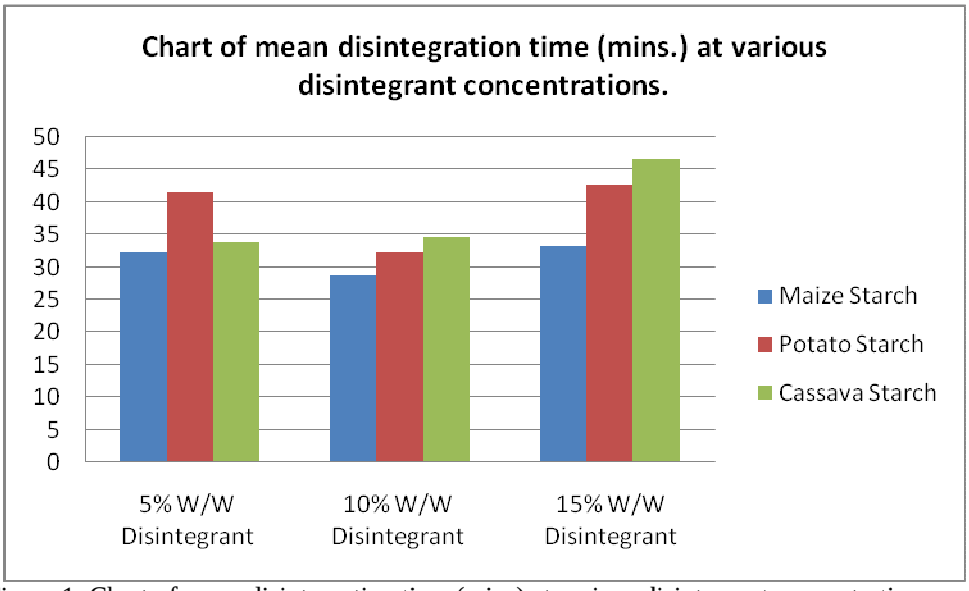

Figure 1: Chart of mean disintegration time (mins) at various disintegrant concentrations.

Table 3(i): Tablet Disintegration Times (Mins)

Tablet S/N	5% Disintegrant			10% Disintegrant			15% Disintegrant		
	MS	PS	CS	MS	PS	CS	MS	PS	CS
1	29.00	39.00	29.00	27.00	30.00	33.00	27.00	42.00	44.00
2	33.00	40.00	30.00	33.00	40.00	33.00	30.00	43.00	46.00
3	35.00	41.00	33.00	29.00	32.00	35.00	30.00	43.00	47.00
4	28.00	40.00	36.00	30.00	35.00	36.00	35.00	41.00	47.00
5	34.00	44.00	37.00	29.00	32.00	35.00	38.00	43.00	48.00
6	35.00	45.00	38.00	30.00	35.00	35.00	40.00	44.00	48.00

MS: Maize Starch; PS: Potato Starch; CS: Cassava Starch.

Table 4: Per cent Concentration Released

Time (Mins)	Amount (%) Released								
	5 % w/w Disintegrant			10 % w/w Disintegrant			15 % w/w Disintegrant		
	MS	PS	CS	MS	PS	CS	MS	PS	CS
1	8.63	18.05	29.41	14.18	10.07	14.29	17.02	11.04	24.49
2	16.41	24.72	35.29	16.19	15.83	20.64	24.11	15.17	29.94
4	21.87	30.56	44.12	39.72	21.59	30.16	38.30	37.24	51.71
8	23.03	51.66	72.06	41.14	33.09	47.62	43.97	63.45	54.43
12	33.09	55.66	77.06	68.09	45.19	67.62	53.05	68.96	63.96
18	38.85	71.67	77.95	79.43	67.35	94.29	58.16	71.73	74.03
24	63.31	80.28	79.42	89.36	79.14	96.83	64.39	75.04	76.20
30	75.56	86.11	83.24	89.93	84.90	97.78	70.92	77.51	78.12
36	89.21	89.44	85.54	90.78	88.64	99.37	76.88	80.83	80.29
42	91.51	90.55	88.24	92.20	94.11	100.96	80.85	86.90	81.10
50	90.64								
60	89.20								

Table 5: Dissolution Efficiency (DE) (%) at 24 Minutes Interval.

DISINTEGRANT	DISSOLUTION EFFICIENCY (%)		
	5 % w/w Disintegrant	10 % w/w Disintegrant	15 % w/w Disintegrant
Maize Starch (MS)	45.47	57.21	64.23
Potato Starch (PS)	57.66	48.24	64.10
Cassava Starch (CS)	70.97	55.27	67.58

Figure 2: Plot of per cent release at 5 % disintegrant concentration

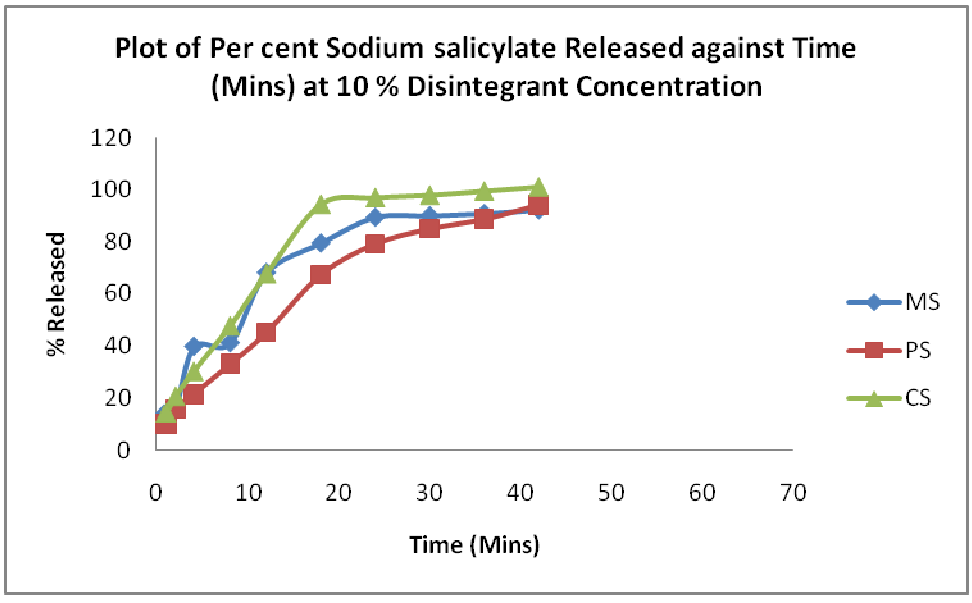

Figure 3: Plot of per cent release at 10 % disintegrant concentration.

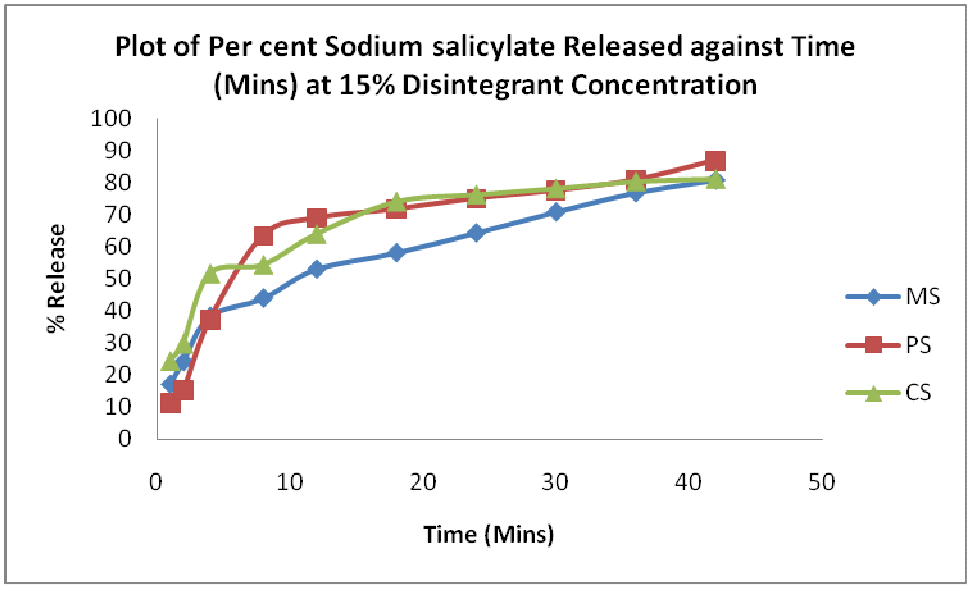

Figure 4: Plot of Per cent Sodium salicylate Released at 15 % w/w Disintegrant

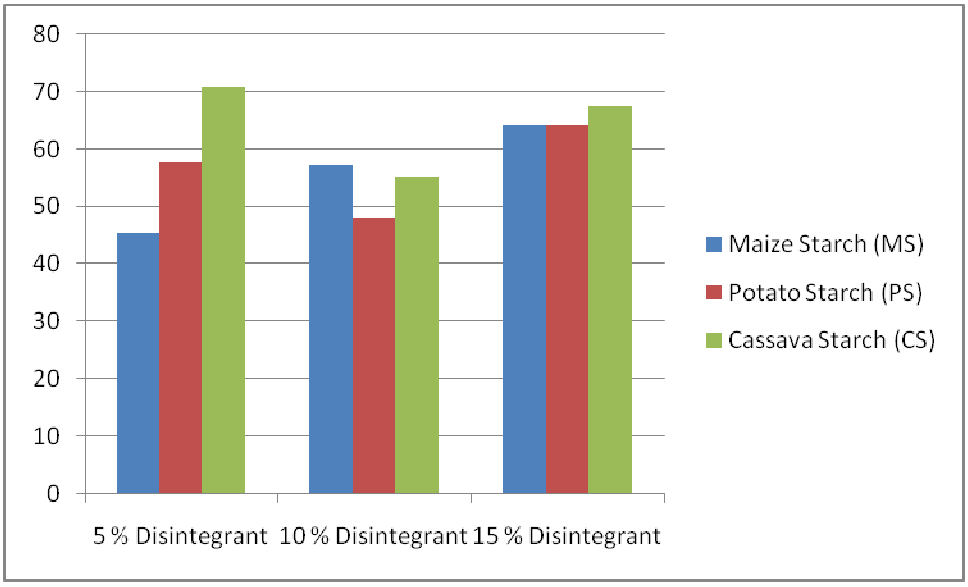

Fig. 5: Chart of Dissolution Efficiency (DE) (%) at 24 minutes interval

by calculating the dissolution efficiencies (DE) at 24 minutes interval as shown in Table 5 and illustrated in Figure 5. At 5 % w/w concentration, DE was as follows: cassava > potato > maize. At 10 % w/w concentration, the order was maize > cassava > potato, and at 15 % w/w, cassava > maize > potato. On the whole, the batch containing 5 % w/w cassava starch had the highest dissolution efficiency of 70.9 % and 5 % w/w maize starch had the lowest of 45.47 %. The result shows that in terms of dissolution, cassava starch was generally the most efficient but at the 10 % w/w concentration which the disintegration test shows to be the optimum, maize starch was the most efficient. It should be noted that the process of dissolution of the active ingredient starts as soon as the tablet is immersed into the dissolution medium even before disintegration starts.

The $T_{50\%}$ and $T_{80\%}$ for different concentrations of the disintegrants indicate times at which 50 % and 80 % of the active ingredient, respectively, must have gone into solution. Within a maximum of 18 minutes, 50 % of the drug had dissolved out of the tablet and within a maximum of about 40 minutes, 80 % had dissolved, for all the batches. Sodium salicylate is soluble in 1 part of water (BP, 1973). Dissolution efficiency calculated as area under the curve at certain time intervals gives an indication of how fast the drug is released into solution from the tablet containing different disintegrant concentrations. The results show that, generally, the DE increases with increase in disintegrant concentration for a particular disintegrant. Cassava starch was the fastest in releasing the drug except at 10 % w/w disintegrant concentration where tablets containing maize starch had the fastest release.

CONCLUSION

From the results, maize starch performed best followed by potato starch and then cassava starch in terms of causing breakage of the tablets into smaller granules in solution. As the concentration of a particular disintegrant increased, the disintegration time generally decreased for up to 10 % w/w of the disintegrants evaluated. Disintegration was optimum at the concentration of 10 % w/w for maize and potato starches, whereas cassava was most efficient at 5 % w/w concentration. Increased concentrations of up to 15 % w/w or more delayed disintegration of tablets for all the three disintegrants evaluated.

From the dissolution test, it was observed that at concentration of 5 % w/w, cassava starch was the most efficient followed by potato starch and then maize starch in releasing the drug into solution. At 10 % w/w concentration, the dissolution efficiency was of the order maize > cassava > potato; at 15 % w/w, it was cassava > maize > potato. Results of granule analysis indicate that granulations obtained in all the batches for the disintegrants had good flow properties. Generally, cassava starch had greater fluff and tapped bulk densities than maize and potato starches. However, the Hausner's quotients and Carr's per cent compressibilities make it obvious that some of the granulations had poor flowability. Although disintegration time is a good parameter for evaluating disintegrants, certain factors relating to the manufacturing process, such as the compression pressure, affect disintegration time of tablets. It is therefore, recommended that these and other disintegrants be further evaluated by other methods such as the capillary tube method. In

one such study, Acdisol was found a far better disintegrant than potato and maize starches (Okorie, 1991), which follows from the general observation that a slight non-adhesive disintegrant with a high water-sorption and pronounced swelling capacity should be quite effective as a disintegrant.

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