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Functionality evaluation of co-processed excipients as diluents in tablets manufactured by wet granulation

Original Paper

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Abstract   Diluents are essential components of a tablet formulation. The type of diluent used in a formulation influences the quality of tablets produced from that formulation. The aim of this study was to evaluate the tableting properties of co-processed excipients (C-PEs) incorporated as diluents in tablet formulation by wet granulation. Metronidazole tablets were prepared by wet granulation incorporating different diluents that were either single component excipients (SCEs) (lactose and microcrystalline cellulose) or C-PEs (Ludipress®, StarLac®, Prosolv® and AVICEL®HFE). The granules obtained for each formulation were evaluated for particle size analysis, flow properties and compression properties. Tablets weighing 500 mg were compressed from the metronidazole granules on a Single Station Tablet Press using a 12 mm punch and die tooling system. The tablets were kept for 24 h post-production, and the properties of weight uniformity, thickness, tensile strength, friability, disintegration time and dissolution profile evaluated subsequently. Results of granule properties showed that variations in parameters evaluated was as a result of differences in the type and composition of diluent used in formulation. Compactibility and tabletability profile of metronidazole granules revealed a better performance with granules processed with C-PE based diluents compared to SCE-based diluents. Tablets formulated with C-PEs as diluents were uniform in tablet weight, disintegrated faster and yielded a faster drug release compared to tablet formulations containing SCEs as diluent. This study reveals the performance advantage of C-PEs as diluents in tablets manufactured by wet granulation and highlights the importance of rational selection of excipients during tablet formulation.

Keywords   *Diluents – co-processed excipients – tablets – wet granulation*

INTRODUCTION

Tablets constitute about 80–90% of dosage forms commonly prescribed by medical practitioners for therapeutic management of disease conditions. It is a solid dosage form that exercises advantages over other dosage forms because of its ease of administration, stability profile and amenable to large-scale production. Tablet making involves the addition of a category of substances known traditionally as excipients. Though commonly referred to as the inactive components of a tablet formulation, they are functional in nature because they contribute significantly to the processing, stability, manufacturability and performance of tablets as a dosage form. Depending on the functionality, excipients may be classified as diluents, disintegrants, binders, lubricants, glidants, etc. They are usually added in stated amounts to facilitate the development of a robust tablet product.

Most tablet formulations are prepared by wet granulation and require the addition of all the listed excipients. One critical excipient that is incorporated in tablet formulations by wet granulation is the diluent. Diluents also known as fillers or bulking agents are routinely added in formulation development to increase the bulk of the formulation and to bind other excipients with the active pharmaceutical ingredient (API). The use of diluents becomes more significant in tablet formulations of low-dose API where the diluent occupies a larger proportion of the formulation. Hence, the properties of diluents become extremely important and can significantly influence the final product property. Studies have been carried out to characterise the mechanical properties of widely used pharmaceutical diluent powders to understand how their mechanical properties impact on the manufacturing performance and properties of the final product (Zhang et al., 2017). These diluent powders are more

or less single component excipients (SCEs) like lactose, starch, mannitol, microcrystalline cellulose (MCC), which have been used in tablet formulation by wet granulation. However, due to the limited functionality of SCEs in tablet formulation, attention has shifted to the development of novel excipients with improved functionality.

Co-processing as a particle engineering technique has been used to develop novel excipients with improved functionality. This technique involves the combination of two or more excipients in optimal proportions at the sub-particle level using a defined method that promotes synergy of properties in composite particles while minimising the limitations of the constituent excipient in the final product. Some of the functionality improvement recorded with co-processed excipients (C-PEs) includes enhanced flowability, compressibility, dilution potential and low lubricant sensitivity and/or moisture sensitivity (Nachaegari and Bansal, 2004). Many of these C-PEs have been designed originally as filler-binders in direct compression formulation (Wang et al., 2015), as superdisintegrating agents for orodispersible tablets (Daraghmeh et al., 2015) and as drug-release retardants in controlled release formulations (Choudhari et al., 2018). No study has reported the use of C-PEs as diluents in wet granulated tablet formulations.

Considering the improved tableting profile of C-PEs, changing the diluent type in a wet granulated tablet formulation from an SCE to a C-PE is likely to result in better tableting properties of the drug product. Hence, the aim of this study is to evaluate the tableting properties of C-PEs as diluents in a wet granulated formulation of metronidazole tablets. Two samples each of lactose-based C-PEs (Ludipress®, StarLac®) and MCC-based C-PEs (Prosolv®, AVICEL®HFE) were evaluated as diluents in comparison to their SCEs (lactose, MCC).

MATERIALS AND METHODS

Materials

Metronidazole (CDH laboratory Chemicals, India), lactose (DFE Pharma, Germany), maize starch (Burgoyne Burbidge & Co. India, Mumbai), Acacia (Kerry Ingredients and flavours Ltd, Ireland), StarLac® (Roquette Pharma, France), Ludipress® (BASF SE, Germany), MCC, Prosolv®, sodium stearyl fumarate (JRS Pharma, Germany), Avicel®HFE-102 (FMC BioPolymer AS, Norway), colloidal silicon dioxide (Evonik Industries, Germany), distilled water.

Preparation of Metronidazole Granules

Metronidazole granules were prepared by wet granulation according to the formulation given in Table 1. A powder blend of metronidazole (20 g), lactose (19.5 g) and maize starch (5 g) was obtained by low shear mixing in a mortar with a pestle (Abdallah et al., 2014). Binder solution was prepared containing acacia ($10\%^w/_w$) and incorporated to mass the powder mix. The wet powder mass obtained was screened through a 1.6 mm sieve to generate granules. The granules

formed were allowed to dry for 20 min in the oven, screened through a 1 mm sieve and then drying completed in the hot-air oven (Gallenkamp BS, England) at 40°C for 2 h.

Characterisation of Metronidazole Granules

Moisture Content

Residual moisture content of each granule formulation was determined using the gravimetric method (Olayemi et al., 2008). A sample of granules (1 g) for each formulation was dried to constant weight in an oven at 105°C for a period of 1 h. The percentage moisture content was calculated using Eq. 1:

$$\% \text{ moisture content} = \frac{initial\ weight - final\ weight}{inial\ weight} \times 100\% \tag{1}$$

Particle Size Analysis

Particle size analysis was carried out using the sieving method as described by Ohwoavworhua and Adelakun (2010). Test sieves ranging from 500 μm to 75 μm aperture size were arranged in a descending order. A sample of granules (20 g) was placed in the top sieve, and the setup shaken for 10 min at an amplitude of 1 mm. The weight of granules retained on each sieve was determined and a plot of cumulative weight (undersize) against sieve size was drawn to extrapolate the median particle diameter (d_{50}).

True Density

True density for each granule formulation was determined using the liquid displacement method (Olayemi et al., 2008). The empty weight of a pycnometer bottle was obtained, filled with xylene, and its weight determined. A sample of the granules (2 g) was transferred into the bottle and the excess liquid wiped off. The new weight was determined, and Eq. 2 was used to compute true density having obtained the weight of xylene displaced by the sample:

$$\rho_T = \frac{weight\ of\ sample \times \rho\ of\ xylene\ (0.864)}{weight\ of\ xylene\ displaced\ by\ sample} \tag{2}$$

Angle of Repose

Angle of repose for each granule formulation was measured using the method described by Pilpel (1965). The angle of repose was calculated using Eq. 4, and a mean of three replicates was reported:

$$\text{Tan } \theta = \frac{h}{r} \tag{3}$$

where h is the height of the cone and r is the radius of the cone base.

Table 1. Formula for preparing metronidazole granules and tablets (n = 100 tablets).

Ingredients	Formulations					
	I	II	III	IV	V	VI
Metronidazole (40%)	20.00	20.00	20.00	20.00	20.00	20.00
Diluent (39%)	19.50	19.50	19.50	19.50	19.50	19.50
Maize starch (10%)	5.00	5.00	5.00	5.00	5.00	5.00
Acacia (10%)	5.00	5.00	5.00	5.00	5.00	5.00
CSD (0.5%)	0.25	0.25	0.25	0.25	0.25	0.25
SSF (0.5%)	0.25	0.25	0.25	0.25	0.25	0.25
Total (g)	**50.00**	**50.00**	**50.00**	**50.00**	**50.00**	**50.00**

Diluents (I – lactose, II – Ludipress®, III – StarLac®, IV – MCC, V – Prosolv®, VI – AVICEL®HFE), CSD – colloidal silicon dioxide, SSF – sodium stearyl fumarate

Bulk and Tapped Densities

Bulk density (BD) and tapped density (TD) were calculated using Eqs. 4 and 5, respectively, according to the method described by USP (2012). The values obtained for BD and TD were used to compute Carr's index (CI) and Hausner's ratio (HR) using Eqs. 6 and 7, respectively:

$$BD = \frac{\text{weight of granules}}{\text{Bulk volume}} \qquad (4)$$

$$TD = \frac{\text{weight of granules}}{\text{Tapped volume}} \qquad (5)$$

$$CI = \frac{TD - BD}{TD} \times 100 \qquad (6)$$

$$HR = \frac{TD}{BD} \qquad (7)$$

Compaction Studies

Compacts weighing 500 mg were compressed at pressures ranging from 40 MPa to 250 MPa on a Hydraulic Carver Press. The compacts were kept for 24 h after compression to allow for elastic recovery. The weight, thickness and crushing strength of each compact was measured, and the parameters of tensile strength and porosity were computed for each compact. Plots of porosity against compression pressure (compressibility), tensile strength against porosity (compactibility) and tensile strength against compression pressure (tabletability) were generated for each granule formulation. The plots were generated with mean values without including standard deviation.

Tableting

Metronidazole tablets were prepared by compressing the granules lubricated with corresponding quantities of CSD and SSF (Table 1) on a Single Station Tablet Press (Type EKO, Erweka, Germany) using 12 mm flat-faced punches at 10 kN. Tablets weighing ~500 mg were obtained and kept for 24 h to allow for elastic recovery before evaluation of tablet properties.

Evaluation of Tablet Properties

Tablet properties for each formulation were evaluated according to BP requirements (2013). The weight of 20 tablets selected at random from each formulation were obtained, and the mean and standard deviations were calculated to ascertain uniformity in weight of tablets for each formulation. The thickness and crushing strength of 10 randomly sampled tablets from each formulation were measured using the Digital Vernier Calliper and Monsanto Hardness Tester, respectively. The mean and standard deviation for each parameter were recorded. The corresponding tensile strength (TS) was calculated for each formulation using the following equation (Fell and Newton, 1970):

$$Ts = \frac{2F}{\pi dt} \qquad (8)$$

where F is the crushing strength, d and t are the diameter and thickness, respectively.

Ten tablets from each formulation were randomly selected, accurately weighed, placed in the chamber of Digital Friability Test Apparatus 903 (Environmental and Scientific Instruments CO., India) and allowed to rotate at 25 rpm for 4 min. Tablets were removed from the chamber, gently cleaned from dust particles and accurately weighed. Friability was calculated in terms of percentage weight loss using Eq. 9:

$$Weight\ loss\ (\%) = \frac{w_i - w_f}{w_i} \times 100\ \% \qquad (9)$$

where w_i and w_f are the weights of the tablets before and after friability test, respectively.

The time taken for six tablets from each formulation to disintegrate was determined using the BJ-3 Disintegration
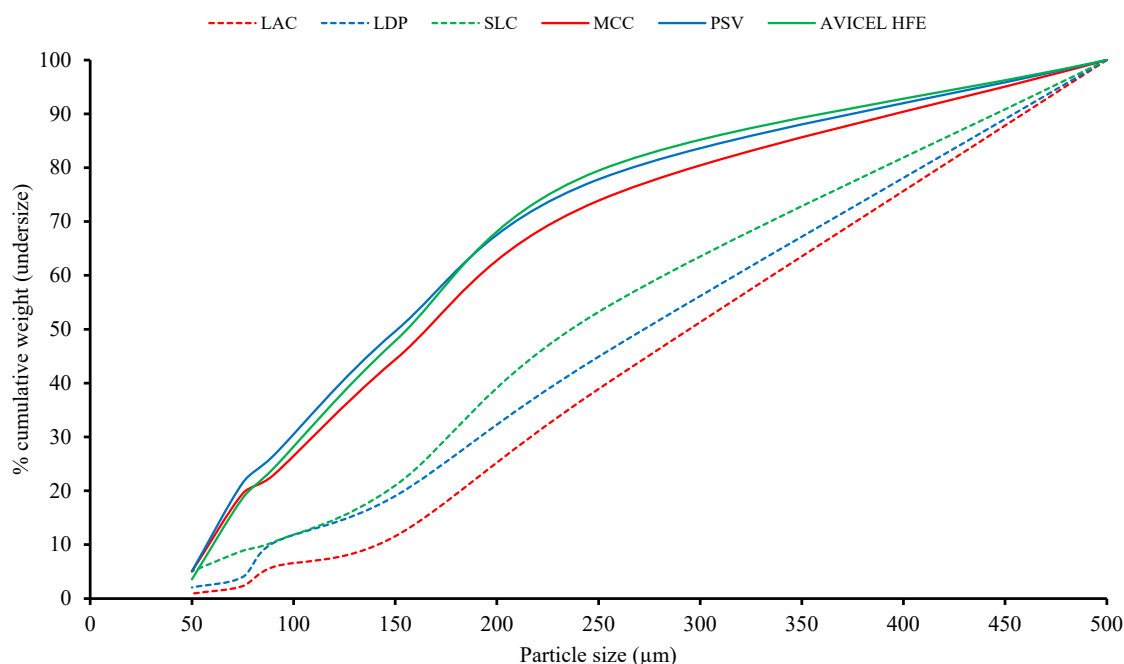
Figure 1. Particle size distribution of LAC (I), LDP (II), SLC (III), MCC (IV), PSV (V), & AVICELÂ®HFE (VI).

Tester (Ningbo Hinotek Instrument Co., Ltd, China). The experiment was conducted in a controlled temperature environment of 37 ± 0.5 °C using distilled water as the medium for disintegration. The mean and standard deviation of six replicates were computed and recorded for each formulation. *In vitro* dissolution studies were conducted according to USP specifications (USP, 2011) using the Tablet Dissolution Test Apparatus (Model 912, Electronics India, Kamli – 173220, Parwanoo, Himachal Pradesh, India). One tablet was placed in a basket submerged in a dissolution chamber containing 900 mL of 0.1 N HCl maintained at 37 °C. The basket was allowed to rotate at 100 rpm, and 5 mL samples were withdrawn after 5, 10, 15, 20, 30, 45 and 60 min of drug release. The dissolution medium was replaced with equal volume of 0.1 N HCl after each withdrawal. The samples collected were filtered and sufficiently diluted with 0.1 N HCl before taking the absorbance readings at 277 nm using the ultraviolet (UV) spectrophotometer (UV-1800 Spectrophotometer, Shimadzu Corporation, USA). The amount of drug released (%) was calculated based on the equation, $y = 0.0395x + 0.1314$, $r^2 = 0.999$, derived from the calibration curve of metronidazole and a plot of drug released (%) against time was generated for the six tablet formulations. The plot was generated with mean values without including standard deviation.

RESULTS AND DISCUSSION

Tablet production by wet granulation involves the addition of a diluent at the formulation stage. The goal of this study

was to evaluate the performance of C-PE as diluents in tablets manufactured by wet granulation in comparison to SCE.

Physical properties of granules prepared using the different diluents consisting of C-PE and SCE materials are summarised in Table 2. Particle size (d_{50}) of granules ranged from 150 μm to 290 μm as extrapolated from the particle size distribution curve (Fig. 1). Lactose-based formulations (I–III) possessed larger particle sizes relative to MCC-based formulations. This may be attributed to the low agglomerating effect of MCC-based excipients when used in wet granulation. It was generally observed that the formulations containing C-PEs as diluents (II, III, V, VI) had lower particle size compared to formulations containing SCEs as diluents (I and IV). This may be linked to the primary particle sizes of C-PEs, which are relatively smaller having been produced by spray drying (Dong et al., 2018).

Angle of repose values for all granule formulations did not exceed 30°, implying that the granules possessed good flow properties (Osei-Yeboah et al., 2014). Generally, tablet formulations prepared by wet granulation are expected to flow well as a result of the agglomeration occurring during granulation leading to particle size enlargement that enhances flow. This is a quality attribute that granules must possess to ensure uniformity in content and weight of tablets during production (Osamura et al., 2018). BD and TD ranged from 0.41 to 0.55 g/cm³ and 0.56 to 0.67 g/cm³, respectively, with lactose-based formulations recording higher values for both parameters. This may not be unrelated to the fluffy and fibrous nature of MCC that results in a higher bulk volume when

Table 2. Physical properties of metronidazole granules prepared with different diluents.

Parameters	Formulations with diluents					
	I	II	III	IV	V	VI
Particle size (d_{50}, µm)	290.00	270.00	235.00	165.00	150.00	155.00
Angle of repose (°)	30.03 ± 0.20	29.63 ± 0.50	28.58 ± 1.87	30.25 ± 0.61	27.52 ± 0.32	28.27 ± 0.56
Bulk density (g/cm³)	0.55 ± 0.01	0.54 ± 0.02	0.48 ± 0.01	0.43 ± 0.03	0.43 ± 0.03	0.41 ± 0.01
Tapped density (g/cm³)	0.66 ± 0.02	0.67 ± 0.00	0.60 ± 0.01	0.62 ± 0.07	0.58 ± 0.01	0.56 ± 0.02
True density (g/cm³)	1.46	1.44	1.54	1.52	1.52	1.54
Carr's Index (%)	16.44 ± 0.32	18.86 ± 3.10	19.28 ± 0.33	30.95 ± 3.37	26.51 ± 2.92	25.79 ± 1.83
Hausner's ratio	1.20 ± 0.00	1.23 ± 0.05	1.24 ± 0.01	1.45 ± 0.07	1.36 ± 0.05	1.35 ± 0.03
Moisture content (%)	5.00	5.00	5.00	7.00	9.00	8.00

I – lactose, II – Ludipress®, III – StarLac®, IV – MCC, V – Prosolv®, VI – AVICEL® HFE

loosely packed resulting in low BD and TD (Chaerunisaa et al., 2019). With respect to CI and HR, MCC-based formulations (IV–VI) were found to be more compressible. Higher values of CI and HR imply better compressibility, while lower values of the same indices correspond to better flowability. The lower particle size of MCC-based formulations tends to promote a greater degree of packing during consolidation of the granules because of significant reduction in powder porosity and lower volume occupied by the granules, which translates to high values of CI and HR.

True density values did not vary significantly across the different granule formulations, though it was observed that granulations formulated with lactose-based diluents (I–III) had relatively lower values in comparison to MCC-based formulations. True density is a measure of intermolecular distance between bonding surfaces and becomes critical in estimating the compaction behaviour of the material. Materials having higher true density correspond to a greater propensity for plastic deformation during compression, leading to tablets of higher tensile strength (Sun, 2011). Moisture content of granules ranged from 5% to 9%, with MCC-based granules having higher values relative to those of lactose-based granules. Slight differences in moisture content may be ascribed to the hygroscopicity of MCC (Sun, 2016). Generally, it was observed that there were variations in granule properties as a result of the type of diluent used in the formulation. In addition, the properties of the granules were also influenced by whether the diluent was either an SCE or C-PE material.

The compressibility–tabletability–compactibility (CTC) profile of the various granule formulation is illustrated in Figs. 2–4. The compressibility plot (Fig. 2) denotes the effect of compression pressure on the porosity of compacts. For all the granule formulations (I–VI), the porosity of compacts was found to decrease with increasing compaction pressure. Compressibility describes the ability of a material to undergo volume reduction when pressure is applied and is usually indicated by a decrease in volume or porosity and a corresponding increase in relative density or solid fraction (Joiris et al., 1998; Upadhyay et al., 2013). For the lactose-based formulations (Fig. 2a), the extent of reduction in porosity did not appear to differ widely across the three granule formulations (I–III). However, it was observed with MCC-based formulations (Fig. 2b) that the extent of porosity reduction differed across the three granule formulations (IV–VI) with MCC granules having the highest degree of compressibility. At 250 MPa, a porosity less than 0.02 was obtained for MCC as compared to 0.04 for AVICEL®HFE and 0.05 for PSV. This may be attributed to the deformation behaviour of MCC, which undergoes extensive plastic deformation during compression, leading to an increased bonding area that promotes compressibility. Hence, in terms of compressibility, MCC, an SCE material had a superior profile compared to C-PE materials. The compressibility of any material is usually determined by many factors like mechanical and particle properties (Sun, 2011).

The compactibility plot displayed as Fig. 3 graphically illustrates the effect of porosity on the tensile strength of compacts. Compactibility refers to the ability of a powder to form coherent compacts under the effect of densification (Sonnergaard, 2006). It describes the relationship between tablet microstructure (porosity) and tensile strength (Sun, 2017; Zeitler & Rades, 2017) For all granule formulations (I–VI), tensile strength of compacts increased with a decrease in porosity. The compactibility profile (Fig. 3a) showed that at a porosity of 0.05, higher tensile strength values were obtained for formulations containing C-PE as diluents (II and III) when compared to the formulation containing SCE as diluent (I). A similar occurrence was observed with MCC-based formulations (Fig. 3b), as higher tensile strength values were obtained at a porosity of 0.05 for formulations containing C-PEs as diluents (V and VI) compared to the formulation containing SCE as diluent (IV). This implies that the compactibility profile of CPEs as diluents was superior to that of SCE material as diluent. Higher compactibility suggests higher inter-particulate bonding. This has been
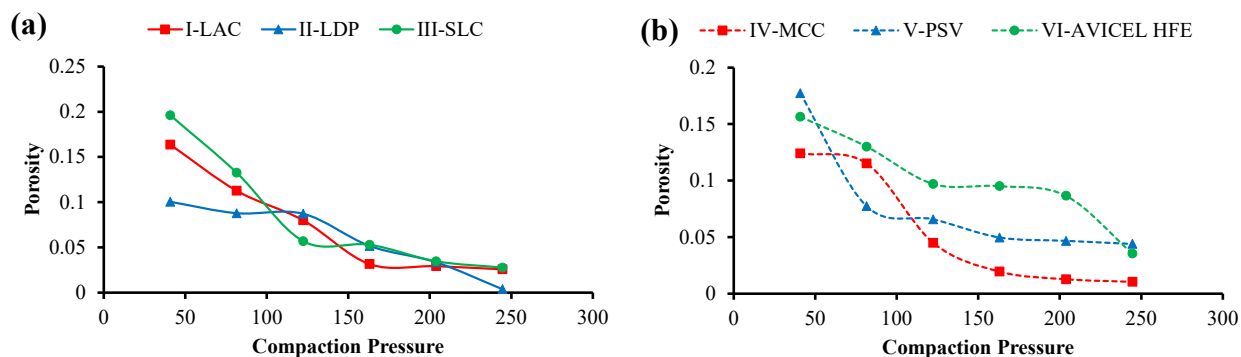
(a)

(b)

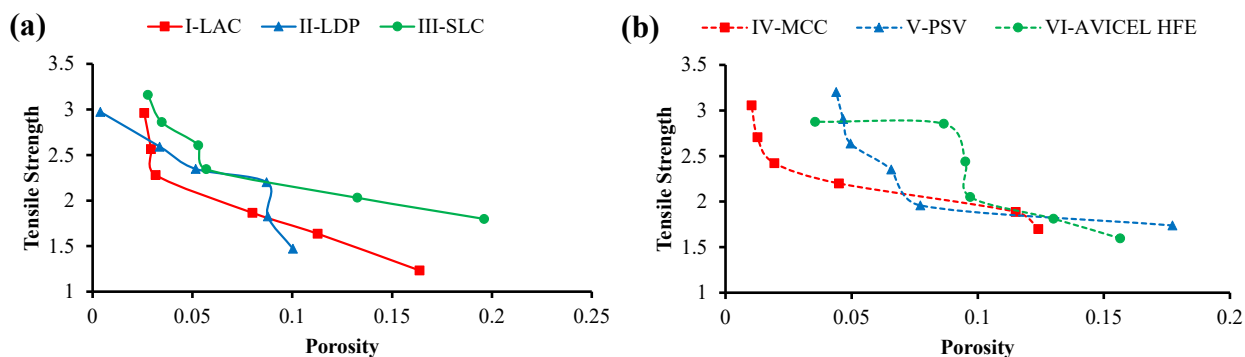*Figure2. Compressibility plot of (a) Lactose-based formulations, (b) MCC-based formulations.*

(a)

(b)

Figure 3. Compactibility plot of (a) Lactose-based formulations, (b) MCC-based formulations.
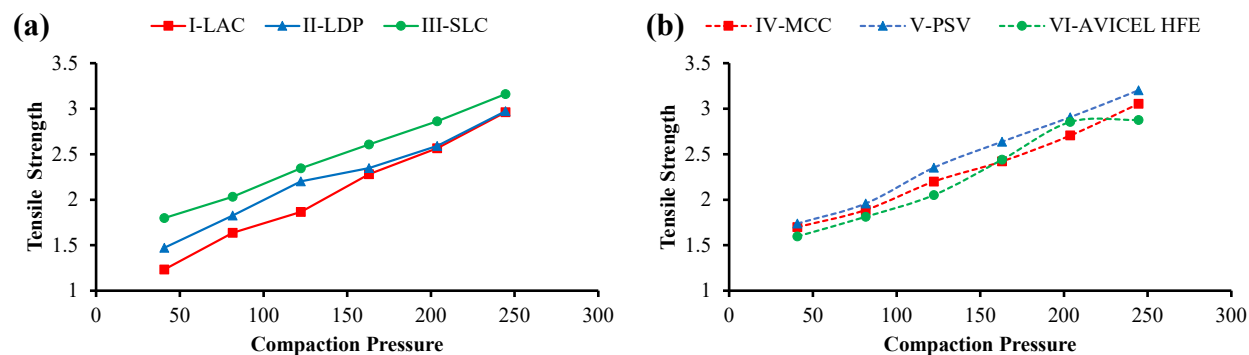
(a)

(b)

Figure 4. Tabletability plot of (a) Lactose-based formulations, (b) MCC-based formulations.

attributed to an increase in interfacial adhesion occurring during compaction, leading to an increase in bonding strength per unit area giving rise to tablets of higher tensile strength at low porosity. Many composite excipients demonstrate an improvement in compactibility as a result of engineering of particle properties during co-processing. This explains why C-PEs performed better as diluents with respect to compactibility when compared to SCEs.

The tabletability profile of all six granule formulations (I–VI) is presented as Fig.4. The plot correlates the relationship between compression pressure and tensile strength of compacts. All the granule formulations displayed an increase in tensile strength with increase in compaction pressure. Formulations containing C-PE as diluents (II, III, V and VI) produced tablets with relatively higher tensile strength across the entire range of compaction pressure in comparison to formulations containing SCE as

Table 3. Physical properties of metronidazole tablets prepared using different diluents.

Parameters	Formulations with diluents					
	I	II	III	IV	V	VI
Mean weight (mg)	503.10 ± 26.62	507.00 ± 11.41	501.80 ± 13.40	511.90 ± 15.21	509.20 ± 12.84	506.00 ± 9.36
Thickness (mm)	4.02 ± 0.13	4.33 ± 0.06	4.38 ± 0.02	4.02 ± 0.05	4.27 ± 0.06	4.08 ± 0.02
Tensile strength (MPa)	0.78 ± 0.12	0.67 ± 0.30	0.57 ± 0.05	1.19 ± 0.11	0.77 ± 0.04	1.20 ± 0.23
Friability (%)	1.20	1.95	2.00	0.78	1.1	0.69
Disintegration time (min)	14.01 ± 1.57	10.99 ± 1.39	10.96 ± 1.08	25.40 ± 0.34	5.77 ± 2.37	0.32 ± 0.06
$T_{80\%}$ (min)	18.00	15.00	14.00	30.00	4.00	35.00

I – lactose, II – Ludipress®, III – StarLac®, IV – MCC, V – Prosolv®, VI – AVICEL® HFE

diluent (I and IV). This implies that C-PE materials used as diluents provided a greater bonding strength per unit surface area, with minimal elastic recovery during decompression stage of tableting, resulting in tablets with relatively higher tensile strength. Improved tabletability profile of C-PEs has been attributed to the material properties of C-PE that combines a plastic deforming excipient and brittle material into the composite structure of the C-PE, thereby reducing the tendency for significant elastic recovery upon ejection of tablet (Nachaegari & Bansal, 2004). Substantial elastic recovery occurring after ejection leads to the breakage of bonds formed during tableting, thereby lowering the tensile strength upon relaxation of tablet. This explains why granule formulations consisting of SCE as diluent returned tablets of lower tensile strength under the effect of compaction pressure. Hence, tabletability is described as the capacity of a powdered material to be transformed into a tablet of specified strength (tensile strength) under the effect of compaction pressure (Joiris et al., 1998; Yadav et al., 2017).

The physical properties of metronidazole tablets prepared using the different diluents is summarised in Table 3. Average tablet weight ranged from 503.1 mg to 511.9 mg. Formulations containing C-PE as diluents (II, III, V and VI) produced tablets with a uniform distribution in tablet weight compared to formulations containing SCE as diluents (I, IV). This implies that the use of C-PE as diluents improved the flow of granules during tableting, resulting in the formation of tablets of narrow distribution in weight. Thickness of tablets did not differ significantly across the various formulations ranging from 4.02 mm to 4.33 mm and could be attributed to the compressibility of the granules that generated the tablets. Tablet hardness was characterised using tensile strength, and values were ranked in the following order, VI > IV > I > V > II > III, with formulations containing C-PE as diluents returning lower tensile strength values compared to formulations containing SCE as diluents. The lowering of tensile strength of tablets formulated with C-PE as diluents may be associated with the inability of the diluents to exert their effect as directly compressible excipients in tablets formulated by wet granulation. Formulation studies

have shown that directly compressible excipients tend to lose their compressibility when incorporated in tablet formulations by wet granulation (Nguyen et al., 2015). Tablet friability parameter was evaluated to measure the weakness of the tablet. Many manufacturers recommend a limit of 1% as tablet friability (Adjei et al., 2017). Only two tablet formulations (IV and VI) passed the friability test. The lactose-based formulations (I–III) did not pass the friability test possibly due to the brittle nature of the diluents used in the formulations. It was generally observed that MCC-based formulations passed the friability test possibly due to the mechanical property of the diluents. MCC-based diluents are known to undergo extensive plastic deformation during tableting, resulting in increased bonding surface area and inter-particulate bonding that produces tablets with higher tensile strength (Edge et al., 2000). Tablet friability of all the formulations corresponded to the tensile strength of tablets. Tablets having lower tensile strength gave rise to high friability and vice versa.

According to BP requirements, immediate release tablets are expected to disintegrate within 15 min. All the tablet formulations passed the disintegration test, except for formulation IV containing MCC as diluent, which failed the disintegration test. MCC is commonly used as a directly compressible excipient because of its exceptional binding properties and prolongs disintegration time when used in concentrations exceeding 15% in tablet formulations (Apeji et al., 2011). It was observed that tablets formulated with C-PE as diluents (II, III, V and VI) disintegrated faster when compared to tablets containing SCE as diluents (I and VI). This has been attributed to the composition of the C-PE, which usually contains an excipient with excellent disintegrant properties like mannitol, starch and crospovidone found in AVICEL®HFE (VI), StarLac (III) and LDP (II), respectively. In addition, the high friability of the tablets must have contributed to rapid disintegration by promoting rapid uptake of water due to high porosity of the tablet created by the relatively high friability.

The rate and extent of drug release from metronidazole tablets was illustrated in Figs. 5 and 6. Drug-release profile
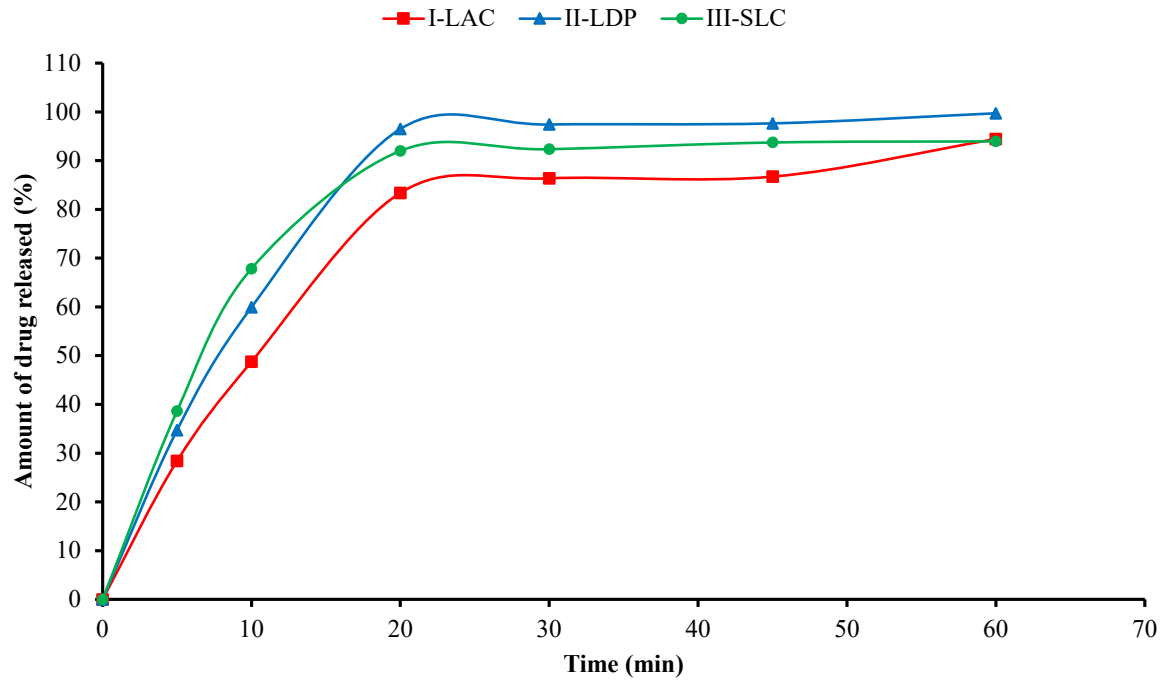
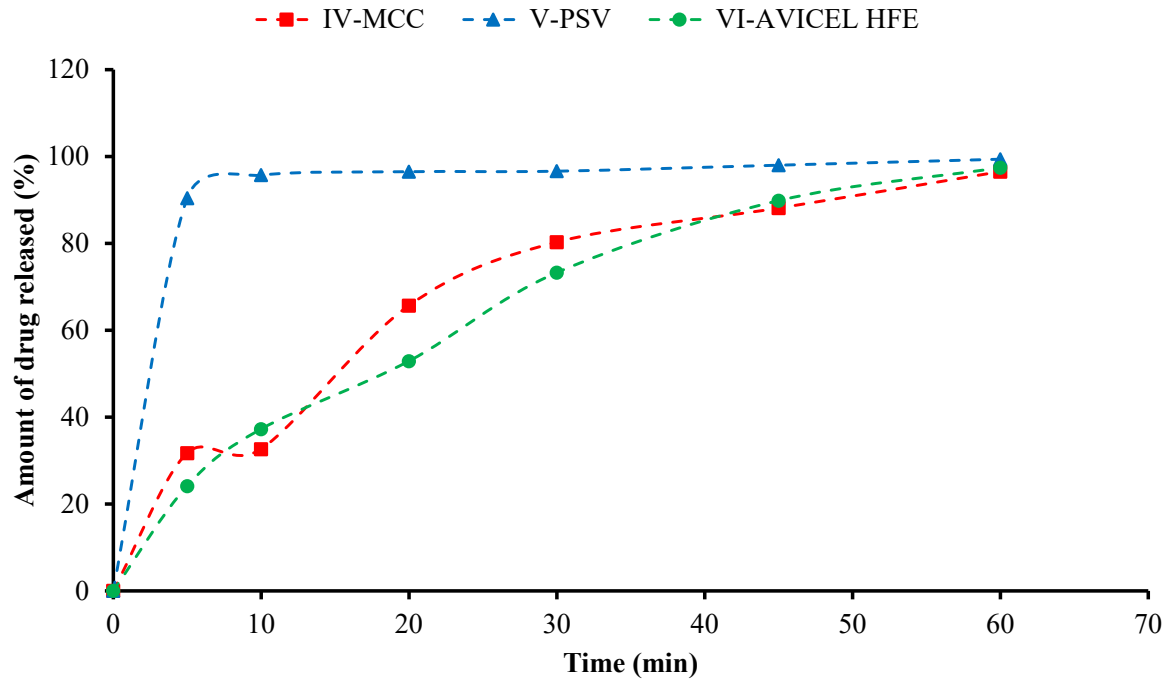*Figure 5. Drug-release profile of Lactose-based formulations.*

Figure 6. Drug-release profile of MCC-based formulations.

for lactose-based formulations (Fig. 5) shows that the rate and extent of drug release was faster with tablets formulated with C-PE as diluents (II and III) compared to drug release from tablets containing SCE as diluent (I).

A similar pattern was observed for the MCC-based formulations (Fig. 6) where tablets formulated with C-PE as diluent (V) gave a faster and more extensive drug release. The rate and extent of drug release for all tablet formulations corresponded with the time it took for the tablets to disintegrate, as presented in Table 3. However, it was not so for tablets formulated with AVICEL®HFE as diluent as the rapid disintegration time did not correspond to faster drug release possibly because of compact crystal structure of mannitol present in AVICEL®HFE, which may have impeded drug solubility (Daraghmeh et al., 2010). Nonetheless, this tablet formulation passed the dissolution test, which was within the USP limits (not less than 85% of the labelled amount of metronidazole should dissolve in 60 mins). All other formulations prepared with different diluents passed the dissolution test.

CONCLUSION

The aim of the study was to evaluate the tableting properties of C-PEs used as diluents in tablets formulated by wet granulation in comparison to SCEs. The properties of the granules prepared using various diluents differed on the basis of the type of diluent (lactose-based or MCC-based) and composition of the diluent (C-PE or SCE). With respect to the compaction properties of granules, C-PE-based formulations performed better in terms of compactibility and tabletability when compared to SCE-based formulations. The tableting properties of the various tablet formulations revealed the superiority of C-PE-based formulations in tablet weight uniformity, disintegration and drug-release profile of the corresponding tablet formulation. This study, therefore, summarises the performance advantages of incorporating C-PEs as diluents in tablets manufactured by wet granulation and underscores the necessity for rational selection of excipients during tablet formulation.

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