ORIGINAL PAPER

https://dx.doi.org/10.4314/njpr.v19i2.5s

Nig. J. Pharm. Res. 2023, 19 (S) pp 47-57
ISSN 0189-8434 e-ISSN 2635-3555

Available online at http://www.nigjpharmres.com

Formulation and Characterization of Ibuprofen Solid Dispersions Using Native and Modified Starches

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of article.

Abstract

Background: Ibuprofen is an anti-inflammatory analgesic drug that is weakly water-soluble with a poor bioavailability.

Objectives: The aim of this study is to formulate ibuprofen solid dispersions by solvent evaporation method using natural polymers (native cassava and genetically modified cassava (GMS), Cassava nanocrystal and corn starches) as possible hydrophilic carriers at varying weight proportions to optimize ibuprofen solubility and dissolution.

Material and Methods: Solvent evaporation method was used to formulate the ibuprofen solid dispersions at different drug polymer ratios. The pure drug and solid dispersions were characterized using Scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), differential scanning calorimetry (DSC), X-ray diffractometer (XRD), particle size, and *in vitro* drug release.

Results: Solid dispersions formulated with starch nanocrystals showed the highest solubility. All solid dispersions prepared with drug:polymer ratio 1:2 generally showed highest solubility. According to the FTIR, the chemical structure of ibuprofen remained intact in the amorphous solid dispersion, but the structure changed from crystalline to amorphous, according to the XRD and the DSC also confirmed this. The scanning electron microscopy showed the solid dispersions were more porous than the pure drug. Higher dissolution rate was observed with nanocrystal solid dispersions with T_{50} (time required for 50% of the medication to be released) between 1.8 and 4.1 minutes.

Conclusion: This study has shown that using these natural polymers increased the solubility and dissolution rate of ibuprofen.

Keywords: Solid dispersion, Cassava starch, Ibuprofen, Genetically-modified starch, Nanocrystal starch

INTRODUCTION

Ibuprofen is commonly utilized as a first-line non-steroidal anti-inflammatory, analgesic, and antipyretic drug though it has a half-life of 1.8 to 2 hours (Eichie *et al.,* 2009). Based on the mechanisms for reporting spontaneous adverse drug reactions in the United Kingdom, ibuprofen is the safest conventional NSAID, hence, the most commonly prescribed and utilized NSAID (Tripathi, 2003). According to Chavez *et al.,* (2003), it is a non-selective cyclooxygenase-1 and cyclooxygenase-2 inhibitor. Though it may not have the same potency as some other NSAIDs in terms of reducing inflammation, it plays a significant analgesic and antipyretic role.

Ibuprofen is one of many medications included in the Biopharmaceutical Classification System (BCS) Class II classification that has strong membrane permeability but poor water solubility (Amidon *et al.,* 1995).

Ibuprofen's rate-limiting stage of dissolution might occasionally cause inadequate absorption as a result of poor and/or delayed dissolution (Mohammed and Behzad, 2007). Several formulations, including inclusion complexes (Ghorab and Adeyeye, 2001), microcapsules (Adeyeye and Price 1994), prodrugs (Murtha and Ando, 1994), etc., are necessary for the pharmacological actions to start working quickly. The oral bioavailability of ibuprofen from various preparations varied greatly, the procedures required longer time and are expensive, and some formulations had poor flow characteristics and handling issues and were bulky. As a result, numerous strategies to deal with the issue of limited aqueous solubility have been created. These include the formation of salts, the use of co-solvents, complexation, the manipulation of solid states, the use of emulsions and surface-active agents, and micronization (Sinha *et al.,* 2013; Chen *et al.,* 2011). Micronization, a traditional process of drug formulation, entails reducing drug powders to sizes between 1 and 10 micrometers. They frequently fail to address the issue of bioavailability and agglomeration which reduces the effective surface area for dissolving which can lead to additional problems. In order to move from micronization to nanonization, the process was then advanced to the next stage. Nanonization is the process of reducing particles that have been micronized to nanoscale dimensions. A range of medications that are poorly soluble in water have been subjected to a number of nanonization procedures to increase their solubility rates and bioavailability. Increased surface area, altered crystalline morphologies, and the creation of novel nanomaterials that can serve as controlled release carriers are some of these initiatives (Chen *et al.,* 2011).

Drug nanocrystals are a cutting-edge and flexible technique for enhancing the solubility and bioavailability of sparingly water-soluble medicines. Drug particle surfaces that have had their surface areas enhanced using the nanocrystal technique have better sticky properties. The utilization of conventional dosage forms along with this ground-breaking nanocrystal technology may further enhance drug therapy (Patel *et al.,* 2018).

Formulation of solid dispersion was introduced and has shown to be the most effective, simple and economical in enhancing drug solubility and dissolution rate of sparingly water-soluble drugs (Leuner and Dressman, 2000).

A solid dispersion is a particular form of solid product that has not less than two distinct parts, frequently a hydrophilic matrix and a hydrophobic medication. The matrix could have crystalline or amorphous characteristics. Amorphous (cluster) particles, crystalline particles, or molecular particles can all be used to disperse the medication (Ford, 1986).

In the preparation of solid dispersions, several water-soluble carriers have been used such as polyethylene glycols (Verheyen et al., 2002; Liu and Desai, 2005), polyvinyl pyrrolidone (Hirasawa et al., 2003; Karavas et al., 2005), poloxamers (Karekar et al., 2009), etc.

Ibuprofen solid dispersion utilizing various carriers has been documented (Tapan *et al.,* 2010 and Khan & Jiabi, 1998).

Numerous researchers have delved into the mechanisms that increase the rate at which solid dispersion dissolves. Eudragit E100 was used by Ehsaneh (2013) to make solid dispersion utilizing a solvent evaporation technique, which boosted solubility and dissolution and led to patient compliance and effective therapy.

The goal of this study was to formulate ibuprofen solid dispersions by solvent evaporation technique using natural polymers (native cassava and genetically modified cassava (GMS), Cassava nanocrystal and corn starches) as possible hydrophillic carriers at varying weight proportions to optimize ibuprofen solubility and dissolution.

METHODOLOGY

Materials

The materials employed were ibuprofen (gift from National Agency for Food Administration and Control NAFDAC)), Poly ethylene glycol 6000, Ethanol (Sigma-aldrich, GmbH, Germany), Cassava and genetically modified cassava tubers (TMED 419) were obtained from International Institute of Tropical

Agriculture (IITA), Corn starch. Other reagents were of analytical grade.

Methods

Extraction of Cassava Starch

Fresh tubers were cleaned, skinned, and cut into cubes about a centimeter in size. They were then blended at a high speed for five minutes. The pulp was stirred for five minutes while suspended in 10 times the volume of water, and then it was filtered through double-fold cheesecloth. The excess liquid was decanted and discarded and left to stand for two hours to allow the starch to settle. The mixture was agitated once more for five minutes after water was added to the sediment. The starch from the filtrate was allowed to settle after the usual repetition of filtering. The sediment (starch) was dried for an hour at 55°C in the oven after decanting the top liquid.

Preparation of Cassava Starch Nanocrystal

Starch nanocrystals were prepared using acid hydrolysis. In 250 mL of 3.16M H_2SO_4, 70g of genetically modified TMED 419 cassava starch was suspended. The suspension was positioned over a water bath that had been heated to a temperature of 40°C. The use of a homogenizer set at 100 rpm guaranteed continuous stirring.

After five days, the suspension was repeatedly centrifuged in distilled water until it was neutral. The aggregate was air dried for 72 hours. The percentage yield was determined. (Oladebeye *et al.,* 2015)

Percentage yield = (Weight of starch nanocrystalobtained) / (Weight of starch used for preparation) X 100

18.05g / 70g X 100% = 27.07%

Preparation of solid dispersion

Solid dispersion was formulated using solvent evaporation technique. The compositions of all the preparations are presented in Table 1. The required amount of drug (ibuprofen), starch nanocrystal obtained from genetically modified cassava starch, native starch, genetically modified cassava starch, standard polymer and surfactant were precisely weighed and transferred into a mortar. The mixture was thoroughly mixed and 80% v/v aqueous ethanol was added and dried at 40^0C. The resulting dried material was pulverized and passed through a sieve 60 to get uniform particle size and transferred to a cellophane envelope for storage.

Characterization of Solid Dispersion samples

Solubility studies

The method of Maruthapillai *et al.,* 2015 was employed. A 2-milliliter microtube was filled with extra solid dispersion, and 1mL of distilled water was added. The mixture was vortexed for 1 minute. For 5 days, each sample was stirred at 100 rpm in a water bath at 25°C. A micropipette was used to gently remove 0.5 mL of the supernatant after centrifugation (5000 g), and the liquid was then properly diluted with ethanol. Ibuprofen concentration was determined using a UV-visible spectrophotometer at a wavelength of 264 nm.

Scanning Electron Microscopy (SEM)

Using SEM, the morphology of ibuprofen and some of the solid dispersions were evaluated. The powders were fixed to a brass stub using double-sided tape before being coated with platinum at a rate of 6nm/min employing a Hitachi ion sputter (E-1030) for 240 seconds at 15mA to make them electrically conductive.

Fourier-Transform Infrared Spectroscopy (FTIR)

The evaluation of ibuprofen and solid dispersion of those exhibiting optimal solubility was conducted using a Fourier Transform Infrared (FT-IR) spectrophotometer (BX 273 Perkin-ELMER, USA). Each sample was properly placed on the sample disc under the scanning pin and assessed using a resolution of $2cm^{-1}$ from $600cm^{-1}$ to $4000cm^{-1}$.

Powder X-ray Diffraction (XRD)

Using an X-ray diffractometer (PAN, Analytical, Netherlands), the materials' polymorphic state (crystallinity or amorphousness) was determined. Using Cu as the anode material, the x-ray diffraction patterns were obtained at room temperature.

Differential Scanning Calorimetry

Shimadzu's Differential Scanning Calorimeter 60 was employed to perform differential scanning calorimetry in order to produce appropriate thermograms. An empty aluminum pan was utilized as a reference, and the precisely weighed sample was put into the pan. Under nitrogen flow, the experiment was run at a scanning rate of 30^0C/min in the temperature range of 50-350^0C.

Dissolution studies

The dissolution was carried out in 900 mL phosphate buffer solution (pH 7.2) at a temperature of 37°C. A USP Dissolution paddle Apparatus type II was used at 100 rpm stirring speed. Each sample was added to the dissolution medium in an amount equal to 0.2g of ibuprofen. 5mL of the aliquot was removed at regular intervals and replaced with 5mL of new medium. Absorbance of the aliquot was determined at a wavelength of 264 nm.

RESULTS AND DISCUSSION

Solubility Studies

Following the oral administration of drugs, dissolution occurs in the gastric and or intestinal aqueous fluids followed by permeation by the drug through the gastrointestinal membranes on the way to systemic circulation. Both processes determine absorption which in turn affects bioavailability. Thus, solubility of the API is critical because it impacts drug dissolution, drug absorption and ultimately therapeutic effectiveness (Jambhekar, and Breen, 2013). The results of the solubility studies for the various formulation codes are given in Fig.2. The solid dispersions were generally more soluble than the pure ibuprofen drug. It was also observed that increasing concentration of polymer in solid dispersions improved the solubility of the drug. This was also observed by other researchers in the formulation of etoricoxib using natural polymers (Sapkal *et al*., 2020). Solid dispersions with drug polymer ratio 1:2 generally had the highest solubility. Solid dispersion formulated with nanocrystal starch gave highest solubility. The reduced particle size of solid dispersion made from nanocrystal caused an increase in surface area and this could have been responsible for the increased solubility.

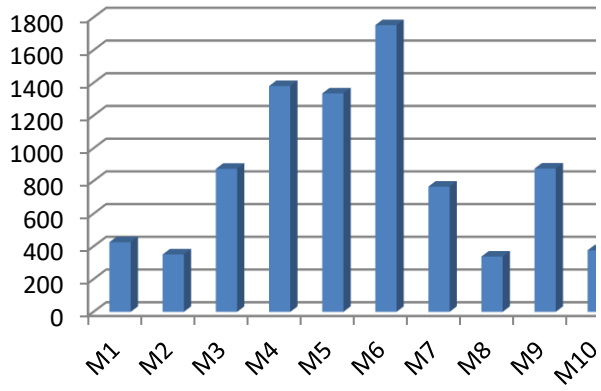
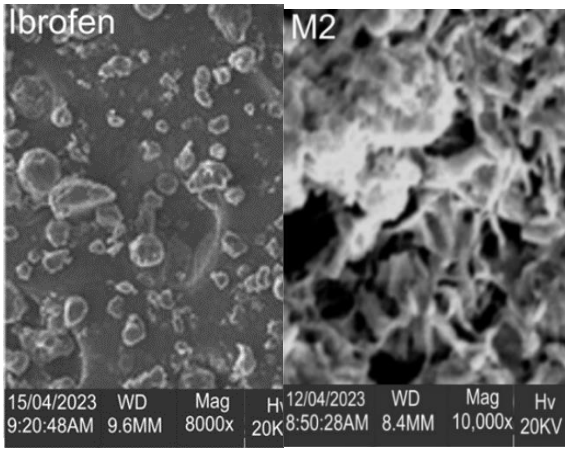


Figure 1: Solubility of solid dispersion formulations

Characterization of Solid Dispersions

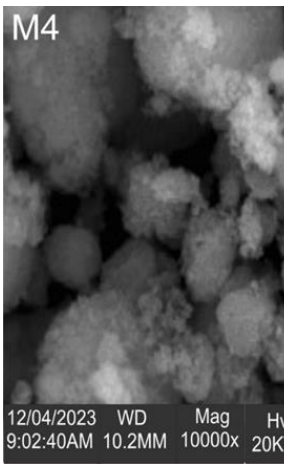
Scanning Electron Microscopy

Scanning electron microscopy (SEM) sheds light on surface topography, size distribution, particle size and particle shape and whether the particles are agglomerates or individual masses. The micrographs of ibuprofen, M2, M4, M9 and M10 are presented in Figures 2(a- e). The micrograph of pure ibuprofen shows particles that are irregular in shape. The surface of the particles reveals the presence of pore-like projections which suggests that the particles are composite structures rather than dense compact masses. The micrograph of formulation M2 has spongy-like shape with clusters suggesting the presence of agglomerates. The micrograph of formulation M4 shows spherical particles that are smaller in size than pure ibuprofen, albeit with roughly spherical clusters suggesting the presence of agglomerates. The micrograph of M9 is significantly different from M4. The particles are spherical in shape and are significantly smaller than the particles of pure ibuprofen. The presence of clusters implies that it may have a tendency to form agglomerates. The micrograph of M10 shows spherical particles.

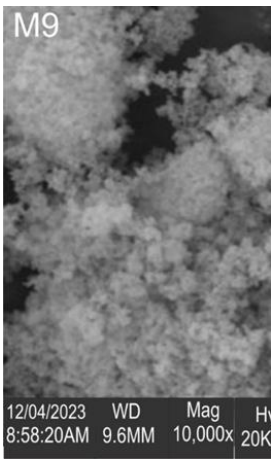


a. Ibuprofen

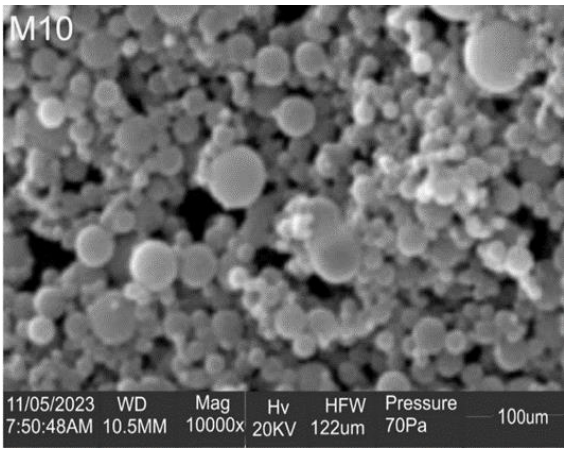
b. Genetically modified starch



c. Starch nanocrystal



d. Native starch



e Corn Starch (standard polymer)

Figure 2: Scanning Electron Micrograph for Ibuprofen and solid dispersion formulations (Magnification: X8000)

Fourier Transform Infrared (FTIR) Spectroscopy Analysis

FTIR spectroscopy can distinguish between the functional groups present in chemical substances and detect interactions between chemical entities due to the formation of new or removal of old functional groups. As a result, the infrared spectrum of chemical compounds reveals a unique fingerprint that can be used to identify them when crosschecked with reference spectra, making FTIR spectroscopy useful in the analysis of drugs and excipients (Andrei, *et al.*, 2011). FT-IR investigations were conducted to determine how drugs and carriers interacted in solid dispersions. Pure Ibuprofen and Ibuprofen solid dispersions' FT-IR spectra were obtained and are displayed in Fig. 3. In accordance with the presence of the carboxyl acid (COOH) in ibuprofen, pure ibuprofen displayed distinct, recognizable peaks at 1703cm^{-1}. The benzene ring is indicated by several minor peaks in the area of 1200-1000 cm^{-1}. These peaks may also be found in the solid dispersions of ibuprofen-carriers, although in this instance, the IR spectra of ibuprofen and the spectrum of ibuprofen solid dispersion exhibits overlap of the carboxyl acid group. Thus, it can be said that there was no chemical interaction between Ibuprofen and Polymers. Similar peaks of pure drug were discovered in the spectra of solid dispersions.

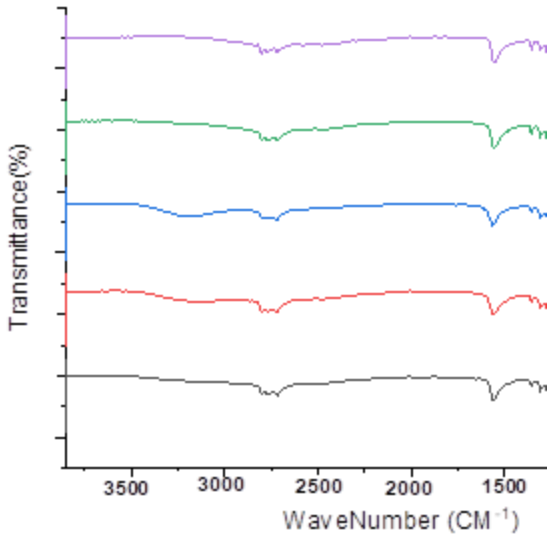


Figure 3: FTIR Spectrum of Ibuprofen and solid dispersion formulations

Powder X-ray diffraction (XRD)

In One of the most crucial characteristics of a drug molecule is its crystallinity, which has a big impact on the solubility and dissolution rate of solute. Due to the phenomena where energy is stabilized by creating crystal bonds, crystalline structure is thought to have a relatively stable structure. Thus, in contrast to the amorphous structure, which represents a higher energy level, its solubility is poor due to its lower energy state. Peak numbers and peak intensity in XRD can be used to determine a substance's level of crystallinity. The more the number and intensity of peak, greater is the crystallinity (Andrei *et al.*, 2015). Consequently, X-Ray Diffractometry was utilized to examine the crystallinity of pure ibuprofen and solid dispersions. The XRD spectra of pure Ibuprofen revealed prominent and intense peaks of crystallinity at a diffraction angle of 2θ at 12.5, 14.2, 23.6 and 28.7 showing the crystalline nature of ibuprofen. The XRD pattern of the solid dispersions revealed reduced peaks with low intensity indicating the drug was changed to the amorphous form except for M10 which had more peaks with great intensity.

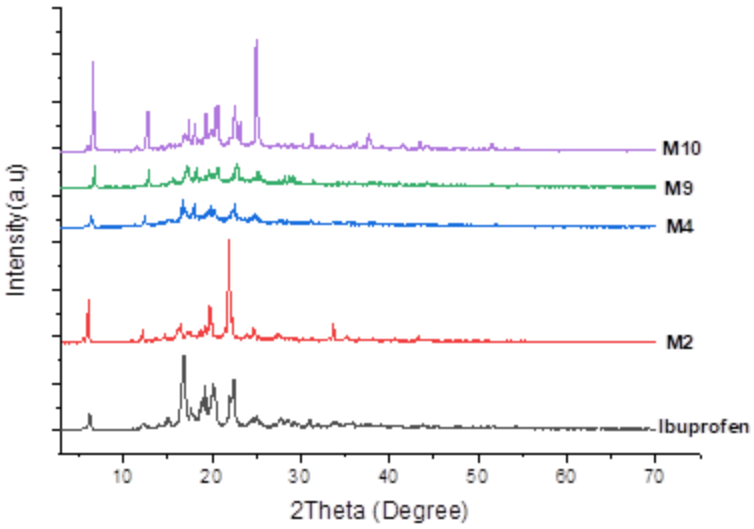


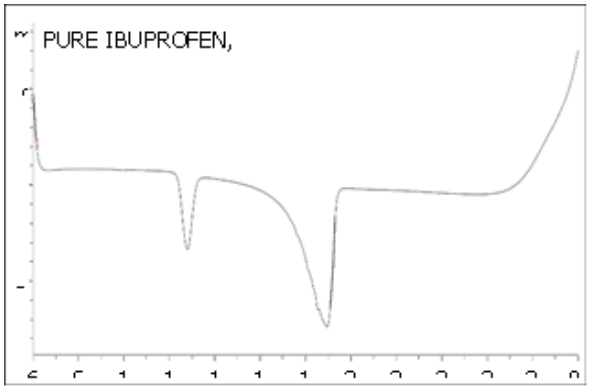
Figure 4: X-ray Diffraction Pattern of Ibuprofen and solid dispersion formulations

Differential Scanning Calorimetry DSC

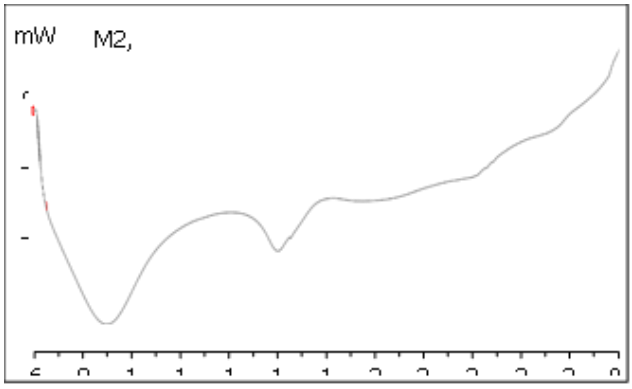
To explore the crystallinity and drug carrier interaction, differential scanning calorimetric investigations of pure ibuprofen and solid dispersions were performed. The thermogram of the pure Ibuprofen indicates endothermic peaks around 126ºC and 190ºC, similar to the melting point of Ibuprofen (Fig. 5.). The endothermic peak of Ibuprofen has high intensity, revealing ibuprofen is highly crystalline. The DSC thermograms of ibuprofen solid dispersions (Fig. 5b-e) showed variations in the nature of the peaks displayed by distinct components; for example, the endothermic peaks of solid dispersions lost its sharpness and distinctive appearance. It revealed that there was no interaction between drug and carrier was discovered but the loss of peaks sharpness may be due to change from crystalline form to amorphous form of the drug.

Particle size

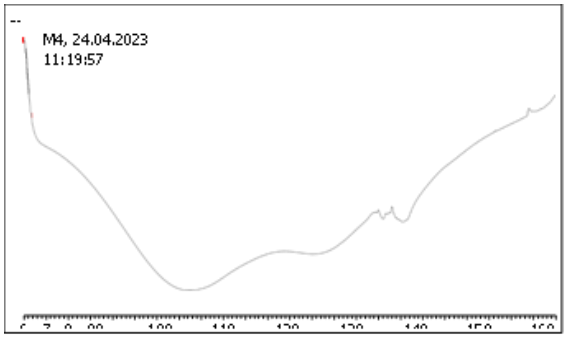
The results of particle size for selected formulations are presented in Table 2. The ranking of the particle size was Ibuprofen > M9 > M2 > M4 > M10. Surprisingly, it was observed that the particle size of solid dispersion made with cassava nanocrystal starch (M4) was slightly higher than those made with corn starch (M10). This could have been due to the agglomeration observed in the SEM of M4.



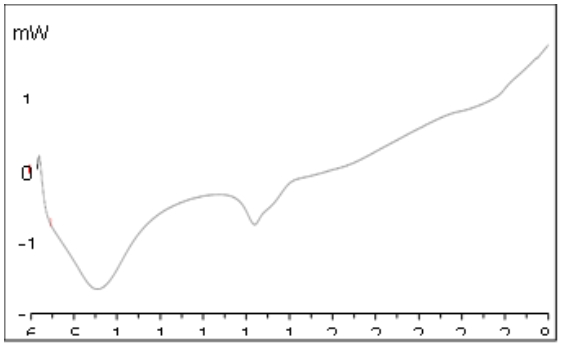
a Ibuprofen



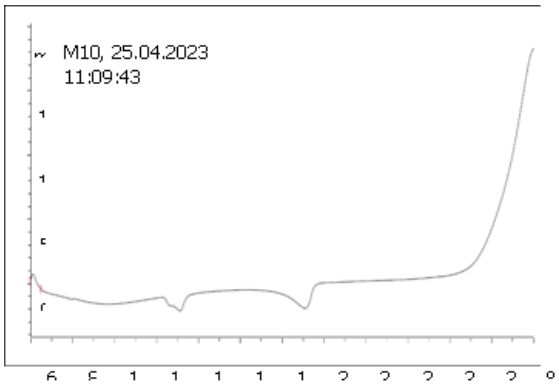
b Genetically modified Starch



c. Starch nanocrystal



d Native cassava starch



e Corn starch (standard polymer)

Figure 5: Differential Scanning Calorimetry Pattern of Ibuprofen and solid dispersion formulations

Table. 2. Average Particle size of Ibuprofen and Solid dispersion formulations

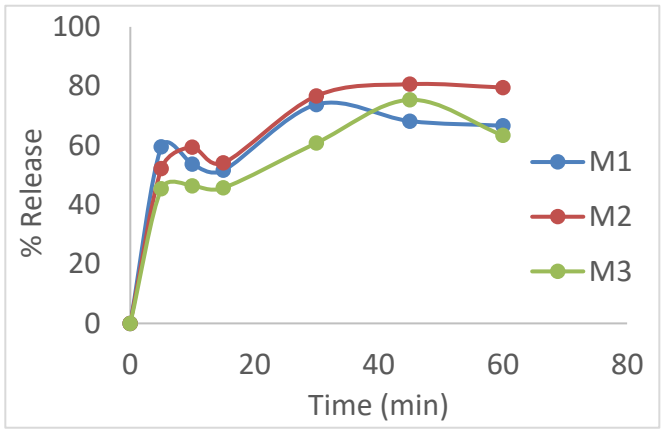
Formulation codes	Average particle size (nm)
IBUPROFEN	124.6
M2	69.52
M4	58.71
M9	75.27
M10	48.06

Dissolution studies

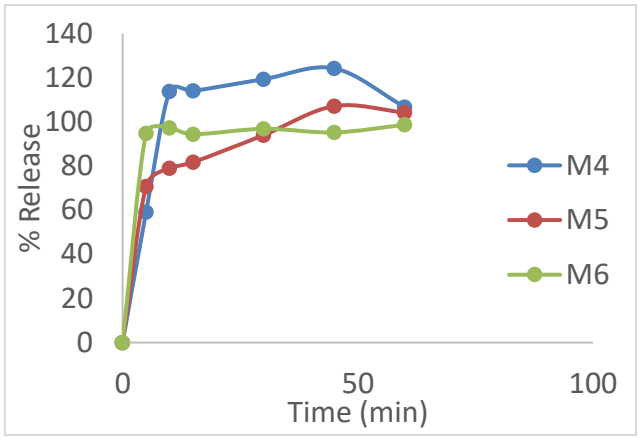
The dissolution profile showing the effect of polymer concentration is shown in figure 6, while the effect of polymer type is shown in figure 7. It was observed that formulations prepared with nanocrystal starch (M4) had the highest drug released (119.32%). It has been said that during production of nanocrystals, there is transformation of crystalline substance into amorphous structure which subsequently leads to increase solubility, thus enhancing the dissolution (Junyaprasert and Morakul, 2015). In Table 3, the T50 for the formulations is shown. The ranking of the T50 for the formulations at 1:2 drug:polymer ratio was M6 < M3 <M9 < M12. Modifications of the polymers also enhanced the dissolution rate of the solid dispersions.

Table 3: Effect of Polymer type and ratio on Drug release

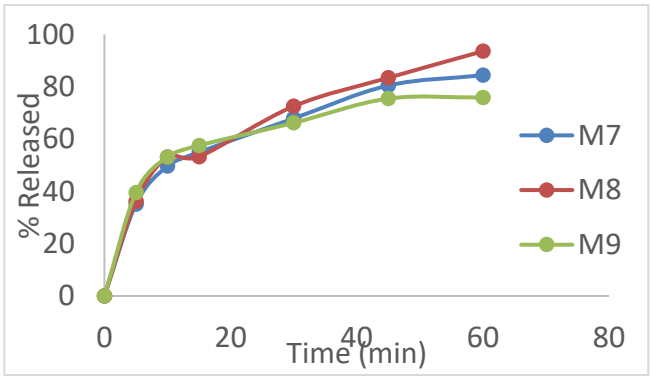
Polymer	Drug : Polymer	Formulation code	T_{50} (mims)
GMC			
	1:1	M1	3.9
	2:1	M2	20.2
	1:2	M3	4.2
Nanocrystal starch			
	1:1	M4	4.1
	2:1	M5	1.8
	1:2	M6	3.0
Native starch			
	1:1	M7	10.0
	2:1	M8	8.0
	1:2	M9	8.4
Corn starch			
	1:1	M10	10.8
	2:1	M11	18.2
	1:2	M12	34.0



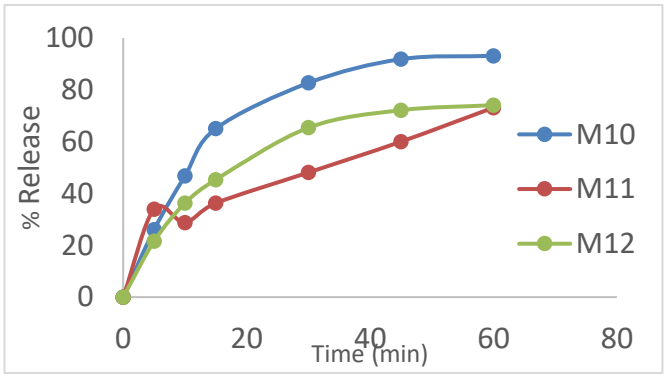
a. Genetically modified Starch



b. Starch nanocrystal



c. Native cassava starch



d. Corn starch (standard polymer)

Figure 6: **Effect of Polymer Concentration on Ibuprofen Release Profile**

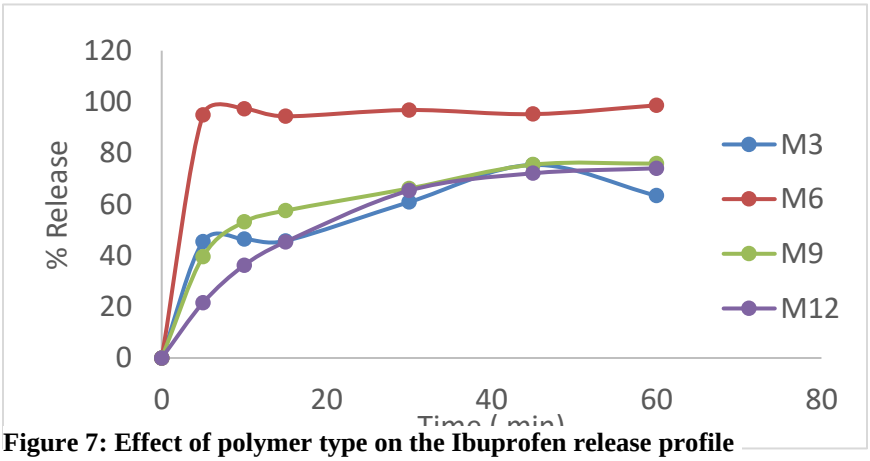


Figure 7: Effect of polymer type on the Ibuprofen release profile (drug: polymer 1:2)

CONCLUSION

According to the current study, solid dispersion of ibuprofen was formed employing several polymers (native cassava starch, genetically modified cassava starch, and nanocrystal cassava starch). The solubility of pure ibuprofen which was 30 µg/mL was improved to about 1725 µg/mL Formulation of solid dispersion changed the crystalline structure of ibuprofen to amorphous form. The dissolution/release rate of pure ibuprofen increased when prepared as solid dispersion. In conclusion, formulation of ibuprofen as solid dispersion increased the solubility and release rate of ibuprofen.

REFERENCES

Adeyeye, C. M and Price, J. C. (1994). Development and evaluation of sustained release ibuprofen-wax microspheres. II. In vitro dissolution studies, Pharm. Res.; 11: 575– 579.

Amidon, G. L., Lennernas, H., Shah, V. P and Crison, J. R. (1995). Theoretical basis for a biopharmaceutical drug classification: the correlation of in vitro drug product dissolution and in vivo bioavaIability, Pharm Res.,12(3): 413-420

Andrei, A., Bunaciu, Vu Dang Huang and Hassan, Y and Aboul-Enein. (2015). Applications of Fourier Transform Infrared Spectrophotometry in cancer diagnostics, Critical reviews in Analytical chemistry vol 45, 156-165

Andrei, A., Bunaciu, Hassan, Y., Aboul-Enein and Serban Fleschin, (2011). Recent applications of Fourier Transform Infrared Spectrophotometry in herbal medicine analysis, Applied Spectroscopy Reviews 46(4): 251-260

Chavez, M. L., DeKorte, C. J and Valdecoxib, (2003). A review Clin Ther; 25(3):817- 851.

Chen, H., Khemtong, C., Yang, X., Chang, X and Gao, J. (2011). Nanonization strategies for poorly water-soluble drugs, Drug Discovery Today,; 662:1-7

Ehsaneh, J. (2013). Preparation,Characterization and Dissolution of Solid Dispersion of Diclofenac Sodium Using Eudragit E-100, J.Pharm. Sci. Vol.3(08) 167-170. http://www.japsonline.com

Eichie, F. E., Arhewoh, I. M and Ezeobi, O.C. (2009). In-vitro evaluation of the pharmaceutical quality of some ibuprofen tablets dispensed in Nigeria,. Afri. J. Pharm. Pharmacol. 3: 491-495

Ford, J.L. (1986). The current status of solid dispersions. Pharm. Acta. Helv., 61: 69-88.

Ghorab, M. K and Adeyeye, M. C. (2001). Enhancement of Ibuprofen, dissolution via wet granulation with betacyclodextrin. Pharm. Dev. Tech. 6:305– 314.

Hirasawa, N., Ishise, S., Miyata, H and Danjo, K. (2003). An attempt to stabilize nivaldipine solid dispersion by the use of ternary systems. Drug Develop. Ind. Pharm., 29: 997-1004.

Junyaprasert, V. B. and Morakul, B. (2015). Nanocrystals for Enhancement of Oral Bioavailability of Poorly Water-Soluble Drugs, Asian. J. of Pharmaceutical Sciences, 10, 1, 13-23.

Karavas, E., Ktistis, G., Xenakis, A and Georgarakis, E. (2005). Miscibility behavior and formation mechanism of stabilized felodipine-polyvinyl pyrrolidone amorphous solid dispersions. Drug Develop, Ind. Pharm., 31: 473-489.

Karavas, E., Georgarakis, E and Sigalas, M. P. (2007). Investigation of the release mechanism of a sparingly watersoluble drug from solid dispersions in hydrophilic carriers based on physical state of drug, particle size distribution and drug–polymer interactions, Eur. J. Pharm. Biopharm 66: 34–347.

Karekar, P., Vyas, V., Shah, M., Sancheti, P and Pore, Y. (2009). Physicochemical investigation of the solid dispersion systems of etoricoxib with poloxamer 188. Pharm. Dev. Technol., 14(4): 373-379.

Khan, G. M and Jiabi, Z. (1998). Preparation, characterization and dissolution studies of ibuprofen solid dispersion using polyethylene glycol, talc and PEG-talk as dispersion carriers, Drug Dev. Ind. Pharm. 24, 455-462.

Leuner, C and Dressman, J. (2000). Improving drug solubility for oral delivery using solid dispersions, Eur. J. Pharm. Biopharm. 50: 47-60.

Liu, C and Desai, K.G. (2005). Enhancement of dissolution rate of valdecoxib using solid dispersions with polyethylene glycol 4000, Drug Develop. Ind. Pharm. 31: 1-10.

Maruthapillai, A., Palanisamy, K and Sunkara, M. (2015). Preparation and characterization of rilpivirine solid dispersions with the application of enhanced solubility and dissolution Rate, Beni-Suef Uni. J. of Basic and Applied Sciences. 2015;4(1):71-109.

Mohammad, A.D and Behzad, T., (2007). Investigation of solid dispersion technique in improvement of physicochemical characteristics of ibuprofen powder. *Iranian J. Pharm. Sci*. **3**, 69-76.

Murtha, J. L and Ando, H. Y. (1994). Synthesis of the cholesteryl ester prodrugs cholesteryl ibuprofen and cholesteryl flufenamate and their formulation into phospholipid microemulsions, *J. Pharm. Sci*. 83:1222–1228.

Oladebeye, A.O., Oshodi, A.A., Amoo, I..A and Karim, A.A. (2013). Morphology, x-ray diffraction and solubility of native and nanocrystals of legume starche, *Int. J. Sci. Res.* 2013; **2**, 172-4.

Patel, V., Sharma, O. P and Mehta, T. (2018). Nanocrystal: a novel approach to overcome skin barriers for improved topical drug delivery, Expert Opinion on Drug Delivery

Sapkal, S.B., Adhao, V.S., Thenge, R.R., Darakhe, R.A., Shinde, S.A., Shrinkande, V.N. (2020). Formulation and Characterization of Solid Dispersions of Etoricoxib Using Natural Polymers, Turkish J. Pharm. Sci. 17 (1):7-19

Sinha, B., Müller, R. H and Möschwitzer, J. P. (2013). Bottom-Up Approaches for Preparing Drug Nanocrystals: Formulations and Factors Affecting Particle Size, Int. J. Pharm., 453, 1, 126-141.

Tapan, K.G., Hemant, B., Amit, A and Dulal, K.T. (2010). Solubility enhancement of ibuprofen in the presence of hydrophilic polymer and surfactant, Int. J. Appl. Biol. Pharm. Tech. 1, 793-800

Tripathi, K.D. (2003). Nonsteroidal anti-inflammatory drugs and anti -pyretic analgesics. Essentials of medical pharmacology, 5th Ed., Jaypee Brothers, New Delhi, pp. 176.

Verheyen, S., Blaton, N., Kinget, R and Van den Mooter, G. (2002). Mechanism of increased dissolution of diazepam and temazepam from polyethylene glycol 6000 solid dispersions, Int. J. Pharm., 249: 45-58.

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Conflict of Interest: None declared
Received: October, 2023
Accepted: December, 2023