RESEARCH ARTICLE
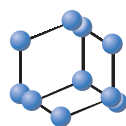
Anti-Inflammatory and Gastroprotective Properties of Aspirin - Entrapped Solid Lipid Microparticles

Salome A. Chime[1,*], Paul A. Akpa[2], Cosmas C. Ugwuanyi[1] and Anthony A. Attama[2]

[1]*Department of Pharmaceutical Technology and Industrial Pharmacy, University of Nigeria, Nsukka 410001, Nigeria;*
[2]*Department of Pharmaceutics, University of Nigeria, Nsukka 410001, Nigeria*

Abstract: *Background*: Aspirin is a nonsteroidal anti-inflammatory drug that is very effective in the treatment of inflammation and other health conditions, however, it causes gastric irritation. Recently, researchers have developed patents (US9757529, 2019) of inhalable aspirin for rapid absorption and circumvention of gastric irritation.

Objective: The aim of this work was to formulate aspirin-loaded lipid based formulation in order to enhance oral bioavailability and inhibit gastric irritation.

Methods: This solid lipid microparticles loaded with aspirin (SLM) was formulated by a modified cold homogenization-solvent evaporation method. *In vitro* studies such as *in vitro* drug release, particle size, Encapsulation Efficiency (EE), micromeritic properties and loading capacity were carried out. Pharmacodynamics studies such as anti-inflammatory and ulcerative properties of the SLM were also carried out in Wistar rats.

Results: The results showed that aspirin entrapped SLM exhibited the highest EE of 72% and particle size range of $7.60 \pm 0.141\mu m$ to $20.25 \pm 0.070\mu m$. Formulations had about 55% drug release at 6h in simulated intestinal fluid pH 6.8. The formulations had good flowability that could facilitate filling into hard gelatin capsule shells. The SLM exhibited 100% gastroprotection against aspirin-induced ulcers ($p < 0.05$). The percentage of anti-inflammatory activities also showed that aspirin-entrapped SLM had 78% oedema inhibition at 7h, while the reference had 68% inhibition at 7h.

Conclusion: Aspirin-entrapped SLM showed good sustained-release properties, enhanced anti-inflammatory properties and total gastric protection from aspirin-induced ulcers and could be used as once-daily oral aspirin.

1. INTRODUCTION

Aspirin is a Nonsteroidal Anti-Inflammatory Drug (NSAID) used for the treatment of pain, inflammation, fever and arthritis [1-5]. It is also an antiplatelet agent recommended for use in elderly patients in order to prevent various heart diseases and stroke due to blood clotting [2, 6]. Aspirin has been found to be efficacious in the treatment of different cancers [7-11]. NSAIDs generally inhibit Cyclooxygenase (COX) enzyme; aspirin specifically and irreversibly inhibits Cyclooxygenase 1 (COX-1) enzyme, unlike other NSAIDs (ibuprofen, indomethacin and naproxen), which reversibly inhibit both COX 1 and COX 2 [5]. However, the use of aspirin and other NSAIDs generally is limited by severe gastric irritation, and aspirin has been penciled down as a major gastric irritant [1, 2]. Aspirin has been formulated as plain tablets, coated tablets, granules, lipid-based formulations and more recently, patented dry powder inhaler [2, 12-16]. Aspirin inhalable formulation is a recent patent that described the development of inhalable aspirin for rapid absorption [12, 13], hence it would prevent aspirin-induced gastric irritation. A formulation of stable parenteral aspirin for the treatment of cardiovascular and other diseases was also developed [15], hence circumventing oral delivery with its limitations. Aspirin has also been formulated as enteric-coated granules as described by Shah *et al.* 2011 (US8057820) in order to prevent stomach ulceration [16]. Bilgiç [17] developed a patent of drug formulation containing atorvastatin and aspirin for treating heart diseases. Humera *et al.* developed an aspirin soft gelatine capsule as single or in combination with other drugs (WO2017095736) [18]. Jaiswal *et al.*, 2017, (WO2017037741) developed aspirin and clopidogrel compact solid dosage form [19]. Here aspirin was enteric coated

*Address correspondence to this author at the Department of Pharmaceutical Technology and Industrial Pharmacy, University of Nigeria, Nsukka 410001, Nigeria; Tel: +2348061329790; Fax: +234-42-770644; E-mail: salome.chime@unn.edu.ng

while clopidogrel was made for fast release in contact with an aqueous medium for the prevention and treatment of cardiovascular diseases. Brenne *et al.,* (WO201501476) 2015 [20], also described the development of aspirin and clopidogrel; aspirin was also co-delivered with prasugrel [21] with enhanced efficacy in treating heart-related diseases. Aspirin and caffeine combinations for enhanced anti-inflammatory properties have been recently described [22]. Aspirin is also co-delivered with other anticancer agents as described in many patents viz: curcumin [23-25], doxorubicin [26], indomethacin [27, 28], sorafenib [29], exemestane [30] and cisplatin [31]. The patents described the application of aspirin as an anticancer drug in combination with other neoplastic agents with enhanced efficacy. Here, we report oral lipid-based delivery systems of aspirin as a single therapy for enhanced efficacy and reduced gastric irritation.

Lipid-Based Formulations (LBF) have a recorded history of protecting the gastric mucosa and GIT generally against the gastric irritation posed by NSAIDs [32-35]. Lipid vehicles for drug delivery are abundant in nature. Some are from renewable sources, they have good stability, biocompatibility with GRAS (generally regarded as safe) status, are biodegradable with high entrapment capacity and may be modified for targeting of drugs to various body parts [36-40]. Recently, many patents on lipid-based formulations for enhanced drug absorption and improved stability have been developed [19].

Richard *et al.*, WO2010017965 (2010) [41], described solid lipid microcapsules containing hGH (human growth hormone). Here, sustained-release preparations of SLM were described for the delivery of hGH. The methods for the formulation of SLM were also described.

Kaur and Verma US9907758 (2018) [42] described processes involved in formulating sustained release vitamin-loaded Solid Lipid Nanoparticles (SLN). He showed that SLN could be used to deliver vitamins. Kaur and Bhandari [43], (WO201310510, 2014) also described the process of preparing SLN entrapping hydrophilic-amphiphilic drug. Zhou *et al*., CN201010112202, 2010 [44], described a novel preparation method of solid lipid nanoparticles. Sobrinho *et al*. WO2018109690 (2018) [45] also described the production of lipid nanoparticles by microwave synthesis. He established that SLN could be formulated by this novel method. Development of solid lipid nanoparticles was also described in some other patents mentioned in this work viz: Burke *et al*., WO2011127255 (2011) [46], Repka *et al.*, WO2015148483 (2015) [47], Weiss *et al.* [48] and Sun *et al*., WO2017041609 (2017) [49], who independently detailed the constituents and methods involved in formulating lipid nanoparticles.

Munhoz *et al.* (2017) [50] described another LBF termed nanostructured lipid carriers, preparation methods and their uses. Mosqueira *et al.* WO2015039199 (2015) [51], also described the development of micro- and nanostructured carriers containing benznidazole and derivatives and their biological uses.

Emulsion based LBF such as Pickering emulsions were developed by Bara, WO2013076673 (2013) [52], and Lauriane *et al.* WO201612452 (2016) [53]. Self-Emulsifying Drug Delivery Systems (SEDDS) [54-58], their constituents, methods of development and applications were also described. Garti *et al.* WO2010150262 (2011) [59], described the formulation methods of reverse hexagonal mesophases (HII) and their uses. Dahl-Kyun *et al.* described the methods involved in the formulation of protein-encapsulated nanoliposome [60].

Other patented LBF have been described in order to enhance the oral absorption of various drugs [61-68] including curcumin [66, 67] and temozolomide [68]. Because of the success recorded by LBFs, this work would focus on formulating SLM of aspirin in order to counteract the effect of this drug in the GIT and also improve their oral bioavailability.

Solid Lipid Microparticles (SLM) are formulations of micrometer range consisting of an inner fat core containing drug stabilized surfactants [69, 70]. The composition of SLM and solid lipid nanoparticle is basically the same, however, the difference is in the size of particles. SLM have a particle size of >1000nm, hence, the routes of administration may be limited [69]. SLM have advantages which include their capacity to encapsulate hydrophilic, lipophilic and natural extracts, hence, the drug may be dispersed or solubilized in the fat core. It also protects loaded drugs from environmental degradation, hence they have high stability and carrier capacity. SLM formulations have the capacity to prevent NSAID induced gastric irritation. Many patents on formulation strategies for solid lipid microparticles, methods of formulation and routes of administration have been developed [71-73]. The aim of the study was to formulate sustained release aspirin-loaded SLM for improved efficacy in the treatment of inflammation and other disease conditions and inhibition of gastric ulceration. SLM could be formulated using different methods [74-76] viz hot homogenization, cold homogenization, spray drying, solvent evaporation amongst others [70]. Here, cold homogenization-solvent evaporation methods using ethanol were chosen as a method of formulating aspirin in order to enhance its stability over time.

2. MATERIALS & METHODS

Aspirin was purchased from Merck KGaA, (Darmstadt, Germany), Phospholipon® 90H was a kind gift from Phospholipid GmbH (Köln, Germany), Softisan® 154 was procured from Schuppen, Condea Chemie (GmbH, Germany), stearic acid, sorbic acid, hydrochloric acid, sodium hydroxide, monobasic potassium phosphate and Tween® 80 were also purchased from Merck KGaA, (Darmstadt, Germany).

2.1. Methods

2.1.1. Preparation of SLM

The lipids comprising P90H, S154 and SA were utilized in ratios of 0.5:2:3 (P90H: S154: SA). They were melted in a beaker using a magnetic stirrer hot plate at a temperature of 80°C with stirring until homogenous. Aspirin was incorporated in the lipid, dispersed homogeneously and allowed to cool and solidify at room temperature. The mixture was transferred into a mortar and pulverised into powder with a pestle. Tween 80 and sorbic acid were dispersed in ethanol. The ethanol mixture and powdered mixture were poured into a beaker and immediately subjected to high shear homogeni-

zation with ultra-Turrax at 5000rpm for 10min. The microemulsion was centrifuged at 16,000xg for 30min using a vivaspin microconcentrator (Vivascience, Hanover, Germany). The sediment obtained was re-suspended in ethanol, filtered and exposed to air to allow the ethanol to completely evaporate [77]. Bland SLM were also prepared in each case according to the composition detailed in Table **1**.

2.1.2. Analysis of Flow Characteristics

The flow properties of the dried SLM were analysed by the indirect method earlier reported [78, 79]. The bulk and tapped densities were determined and used in calculating the Hausner's quotient and Carr's compressibility index [80, 81].

2.1.3. Morphology and Particle Size Analysis

The SLM were dispersed in water and placed on a microscope slide covered with a slip. A moticam (Moticam, China) attached to a Hund binocular microscope was used to determine the morphology and particle size at x100 magnification [82, 83].

2.1.4. Encapsulation Efficiency Determination

A 100mg of aspirin SLM was dispersed in 40ml of water and heated at 70°C for easy dispersion, it was made filtered using a double filter paper (Whatmann no 1) and made up to 100ml in a volumetric flask. Adequate dilutions were made and absorbance readings were read at 225nm using UV/Vis spectrophotometer UNICO 2102 (UV/Vis Spectrophotometer, USA). The drug content was determined with reference to a prepared Beer-Lambert's plot for aspirin in water. EE was then calculated:

$$EE\% = \frac{ADC}{TDC} x100 \qquad (1)$$

ADC = Actual Drug Content, TDC = Theoretical Drug Content (Eq. 1) [84, 85].

2.1.5. Loading Capacity (LC)

Loading capacity analyses the relationship between encapsulated drug and the lipids viz (Eq. 2) [86, 87]:

$$LC\% = \frac{Quantity\ of\ encapsulated\ drug}{lipid\ amount} x100 \qquad (2)$$

2.1.6. In Vitro Release and Kinetics of Release

Two media, namely simulated gastric fluid without pepsin (SGF, pH 1.2) and simulated intestinal fluid without pancreatin (SIF, pH 6.8) were employed for release using the USP apparatus I (rotating basket). 500ml of freshly medium which was maintained at a temperature of 37 ± 1°C was used in the study. About 100mg of the aspirin SLM formulation was transferred into a dialysis membrane previously soaked for 12h in the medium, containing 5ml of the medium [88-90]. It was placed into the basket and rotated for 150rpm. About 5ml of the medium was withdrawn and replaced with fresh medium at intervals. After UV analysis, the content of aspirin per time was calculated using already prepared Beer's plot.

Using drug content values (Q%), the following plots were prepared: cumulative drug release versus time (zero-order) [91, 92], log cumulative of % drug remaining vs. time (first-order kinetics model), cumulative % drug release vs. square root of time (Higuchi model) [93], and the integral form of Higuchi, log cumulative % drug release vs. log time, log fraction of drug release versus log time [94] and Ritger-Peppas plots [95].

2.2. Anti-Inflammatory Studies

All protocols of the animal experiment were duly followed by the institution. The rat paw oedema test was carried out to analyse the anti-inflammatory potentials of aspirin SLM using egg albumin as the phlogistic agent [96, 97]. Wistar rats of both sexes (90-150g) divided into four experimental groups of five for each group were used and fasted half a day without giving them water for uniform hydration. Aspirin-loaded SLM equivalent to 200mg/kg dose were given orally to the rats. The reference group received 200mg/kg of pure sample of aspirin and the control group received 10ml/kg of distilled water. Thirty minutes' post treatment, oedema was induced through egg albumin injection into the rats' right hind paw. The volumes of distilled

Table 1. Composition of SLM.

Batch	Lipid Carrier (%)*	Aspirin (%)	Tween® 80 (%)	Sorbic Acid (%)	Ethanol qs (%)
A	10	0.0	1.5	0.1	100
B	10	0.5	1.5	0.1	100
C	10	1.0	1.5	0.1	100
D	10	2.0	1.5	0.1	100
E	15	0.0	1.5	0.1	100
F	15	0.5	1.5	0.1	100
G	15	1.0	1.5	0.1	100
H	15	2.0	1.5	0.1	100

*Lipid Matrix Carrier (LMC) consisted of Phospholipon 90H (P90H), Softisan 154 (S154) and Stearic Acid (SA) at ratios 0.5:2:3 respectively. Batches A, B, C and D were formulated with 10% of LMC and 0, 0.5, 1 and 2% w/w of aspirin respectively; Batches E, F, G and H were formulated with 15% of LMC and 0, 0.5, 1 and 2% w/w of aspirin respectively.

water displaced by the hind paw were determined with a plethysmometer at 0, 0.5, 1, 2, 3, 4, 5, 6, 7 and 8 h. The percent oedema inhibition was calculated (Eq. 3) as:

$$Oedema\ inhibition\,(\%) = \frac{Vo - Vt}{Vo} X100 \qquad (3)$$

Vt = volume of oedema at the corresponding time, Vo = volume of oedema in control rats at the same time [96].

2.3. Ulcerative Studies

After the Anti-Inflammatory study that lasted for 8 h, the rats were sacrificed by ether anaesthesia and their gastric mucosae were examined for ulcer with the aid of magnifying hand lens. The lesions were counted and divided into large lesions > 2mm, small for lesions measuring about 1-2mm, while the pinholes were lesions < 1mm. The severity of damage to the mucosa was analyzed as: No lesions or one puntiform lesion (0); two to five punctiform lesions (1); one to five small ulcers (2); more than five small ulcers or one large ulcer (3); more than one large ulcer as previously described (Score = 4) [98, 99].

2.4. Data Analysis

The data were analyzed by One-Way Analysis of Variance (ANOVA), Excel 2016 and differences between means were assessed by a two-tailed Student's t-test. P < 0.05 were considered statistically significant.

3. RESULTS & DISCUSSION

3.1. Encapsulation Efficiency and Loading Capacity

The results of the EE of aspirin in the SLM are shown in Table **2** and show that the highest EE of 72% was obtained in SLM formulated with 10% (Batches C) of the lipid carrier and containing 1% of aspirin. However, the SLM formulated with 15% of lipid carrier had the highest EE of 70% for SLM containing 0.5% of the aspirin (Batch F). The results were significantly affected by the loaded drug; formulations containing 2% of aspirin showed significantly (p < 0.05) lower

EE values (38% and 52%, Batches D and H). However, increasing the content of lipid matrix beyond 10% did not significantly increase encapsulation.

The results of the loading capacity of lipid carriers are also shown in Table **2** and show that LC increased with drug concentration in agreement with previous research [2].

3.2. Particle Size and Morphology

The results of the photomicrographs of the aspirin-loaded SLMs are shown in Fig. (**1a** & **1b**) and showed that the particles were spherical. The results of the particle size are shown in Table **2** and show that the particle size ranged from 12.3μm to 20.3μm for aspirin-entrapped SLM formulated with 10% of lipid carrier, while, those formulated with 15% of lipid had a particle size of 14.3μm to 18μm. Particle size increased with EE as shown in Table **2**. Particle size may be affected by drug loading, lipid carrier, and homogenization speed amongst others. The results showed that particle size was neither significantly (p < 0.05) affected by an increase in drug loading nor an increase in the amount of lipid carrier used in formulating the SLM. These results were however, in agreement with previous research [2, 32].

3.3. Yield

The results of the yield or percentage recovery of SLM are also shown in Table **2** and show that the highest yield of 79.6% was obtained. The results revealed that there was generally high percentage yield in all the formulations, that attests to the reproducibility of this technique, hence aspirin could be formulated using this method, which is simple and involves simple technology.

3.4. Flow Properties

The flow properties of aspirin-entrapped SLM are shown in Fig. (**2**) and revealed that Carr's compressibility indices ranged from 7 to 23 %, while, Hausner's ratio ranged from 1 to 1.27. Carr's compressibility index range of 5-15 % indicated excellent flow [74-76], while values between 18-20

(a)   **(b)**
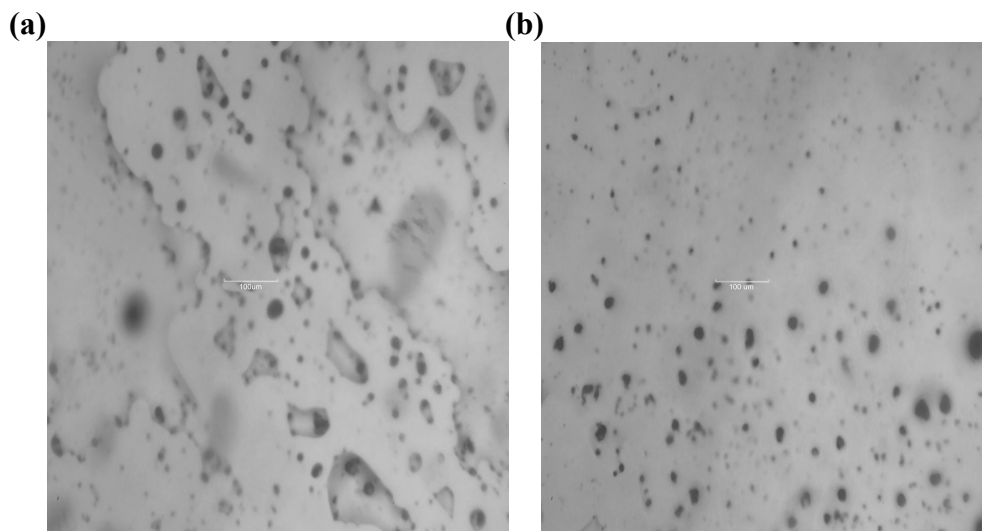
Fig. (1). Photomicrographs of SLMs formulated with (**a**): Lipid carrier 10% and 1% of aspirin (Batch C); (**b**): Lipid carrier 15% and 0.5% of aspirin (Batch C).

Table 2. **Some Properties of Aspirin-Entrapped SLM.**

Batch	Encapsulation Efficiency (%)	Loading Capacity (mg drug/100mg Lipid)	Yield (%)	Particle Size (µm $\pm$ SD)
A	-	-	69.83	9.05 ± 1.06
B	67	3.367	64.79	12.31 ± 0.23
C	72	7.278	62.54	20.25 ± 0.17
D	38	7.659	70.00	14.30 ± 0.13
E	-	-	67.95	7.60 ± 0.14
F	70	2.341	70.18	18.25 ± 0.35
G	56	3.763	79.55	16.33 ± 0.53
H	52	7.42	64.52	14.20 ± 0.27

Batches A, B, C and D were formulated with 10% of LMC and 0, 0.5, 1 and 2% w/w of aspirin respectively; Batches E, F, G and H were formulated with 15% of LMC and 0, 0.5, 1 and 2% w/w of aspirin respectively.
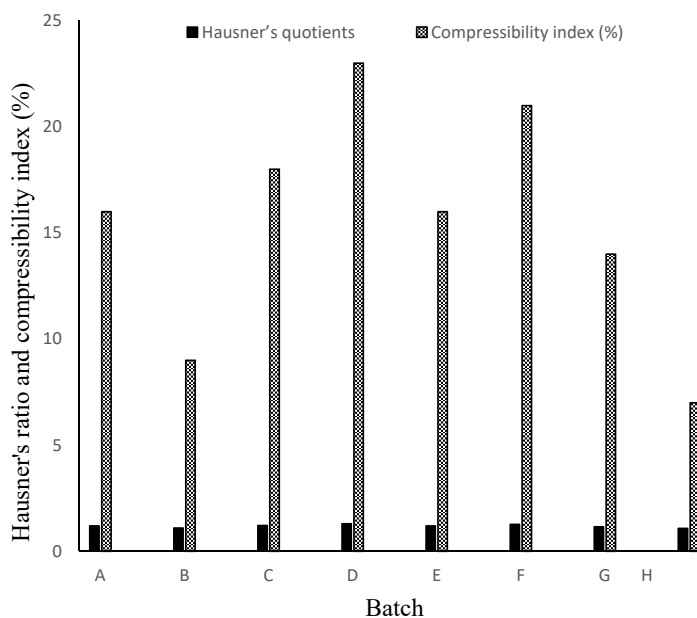
Fig. (2). Flow properties of aspirin-entrapped SLM; Batches A, B, C and D were formulated with 10 % of LMC and 0, 0.5, 1 and 2% w/w of aspirin respectively; Batches E, F, G and H were formulated with 15% of LMC and 0, 0.5, 1 and 2% w/w of aspirin, respectively.

indicated fair flow [77]. Hence, the SLM had good flowability that could facilitate filling into capsule shells and therefore, be produced on a large scale by Pharmaceutical industries. Hausner's ratio range of 1-1.2 also indicated good flowability.

3.5. *In Vitro* Release and Kinetics of Release

The results of the *in vitro* release of aspirin from SLM in SGF without enzyme are shown in Fig. (**3a**), and showed about 30 to 60% drug release (Batches C and F) at 3h. Formulations with 15% lipid carrier significantly exhibited higher drug release at time intervals than the SLM containing 10% of lipid carrier (p < 0.05). This revealed that the entrapped drug in the SLM with 10% lipid carrier (Batch C)

was in the inner fat core of the SLM, yielding higher sustained drug release. In SIF (pH, 6.8) (Fig. **3b**), about 29% of aspirin was released at 6h by Batch C with 10% lipid carrier, while Batch F with 15% lipid carrier had about 56% aspirin release at 6h, hence both formulations had good sustained release properties and were recommended for once-daily oral administration. However, SLM formulated with 10% of lipid carrier (Batch C) also exhibited significantly (p < 0.05) lower release of drug at an interval which may due to entrapment of the drug in the inner phospholipid compartment of the SLM leading to gradual and more sustained drug release. This showed that reducing the viscosity of the formulation by reducing the concentration of the lipid carrier prior to homogenization yielded formulation with better encapsulated drugs, which may also increase the stability of the en-

trapped drugs by totally shielding them away from environmental conditions.

The results of the *in vitro* release kinetics and mechanisms of release are shown in Fig. (**3**). The zero order plots (Fig. **4a**) of the amount released and time were linear only for Batch C (R^2 = 0.9) [78, 79]. The first order plots (Fig. **4b**) were linear for the two batches C and F, showing that drug release also followed first-order release kinetics [91, 92]. Higuchi plots (Fig. **4c**) were linear for both formulations which revealed that diffusion was one of the mechanisms of drug release [93]. However, Ritger-Peppas plots (Fig. **4d**) showed that drug release followed Fickian diffusional release mechanism ($0.43 < n < 1.00$) in all the batches (non-swellable spherical matrix), which indicated that drug release was basically by diffusion [95].

### 3.6. The Anti-Inflammatory Properties

The results of the anti-inflammatory properties of the aspirin-entrapped SLM are shown in Table **3** and show that the formulations exhibited properties related to drug release in SIF. Peak effect was observed for both batches at 7 and 8h, respectively. Hence, at 7h, and 8h respectively, the SLM exhibited percent oedema inhibition of 78% respectively, significantly higher than the reference sample which showed 67% inhibition ($p < 0.05$). Hence, the LMC enhanced the *in vivo* absorption of aspirin and also sustained their release profiles. Lipids and surfactants generally improve the oral bioavailability of most drugs by acting as permeability enhancers. Increased permeability is achieved when the efflux pump is inhibited by lipids and polysorbates [100].
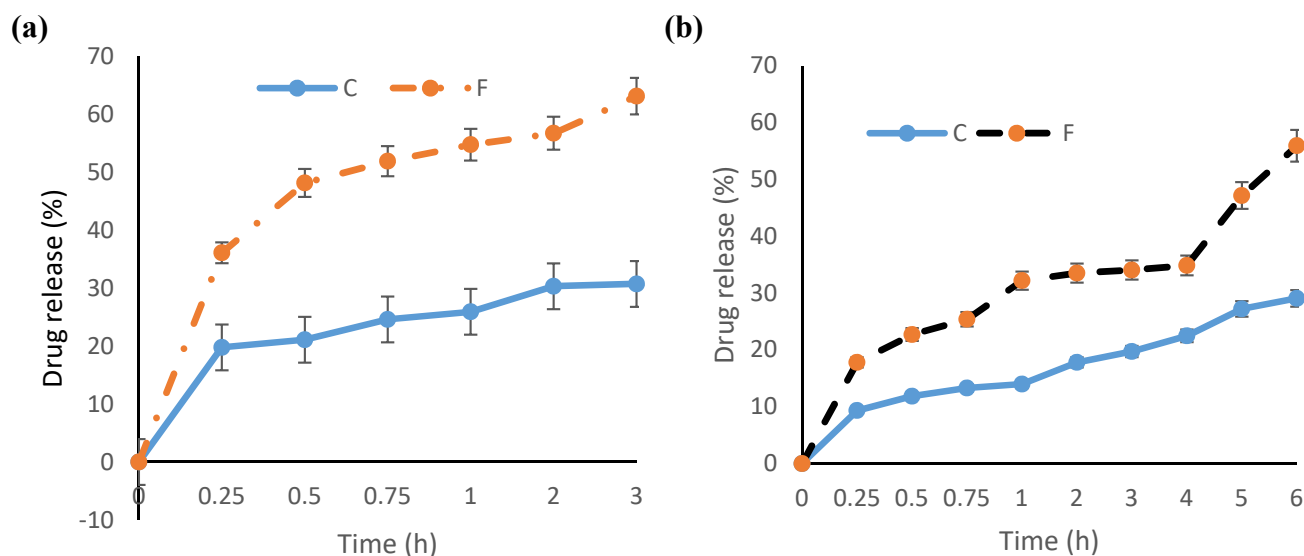
Fig. (3). *In vitro* release profiles of aspirin-entrapped SLM in (a): Simulated gastric fluid (SGF, pH 1.2) and (b): Simulated intestinal fluid (SIF, pH 6.8). Batch C was formulated with 10% of lipid carrier and 1% w/w of aspirin, while Batch F was formulated with 15% of lipid carrier and 0.5% w/w of aspirin respectively.

(c)
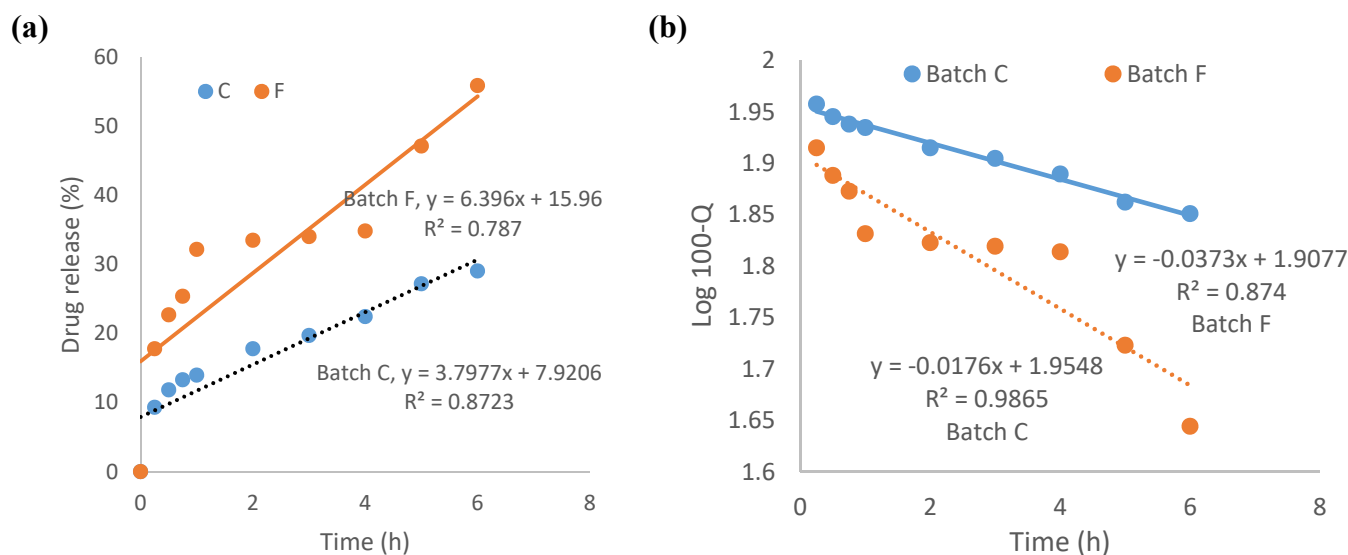
(d)
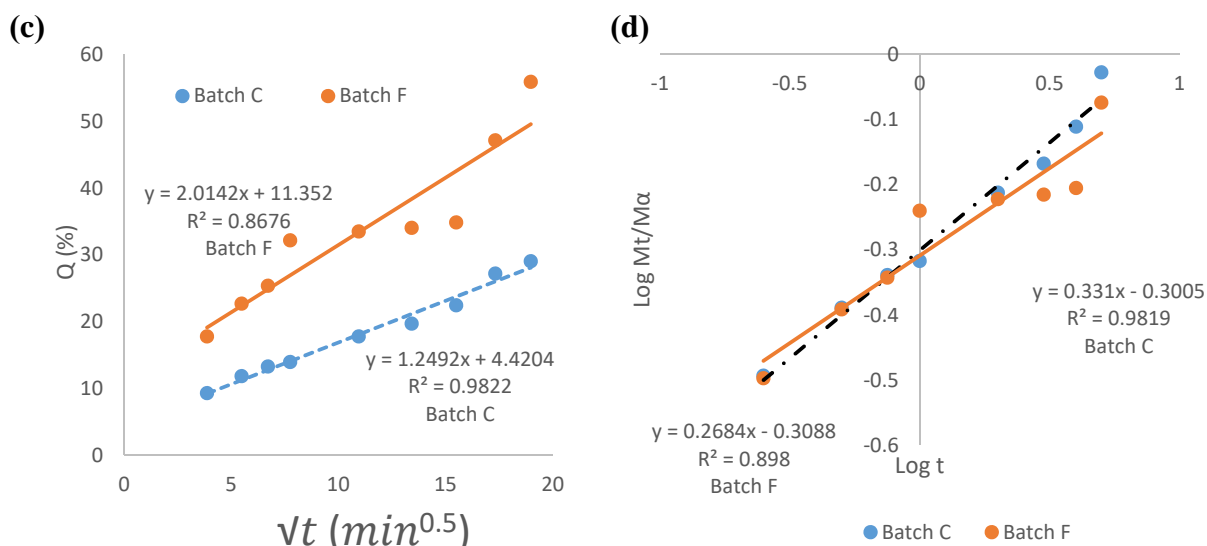
Fig. (4). Release kinetics of aspirin-entrapped SLM in SIF, (a): Zero-order plots, (b): First-order plots, (c): Higuchi plots, (d): Ritger-Peppas plots for Batches C and F formulated with 10 and 15% lipid carrier and 1% and 0.5% aspirin respectively.

Table 3.   Anti-Inflammatory Properties of Aspirin Entrapped SLM.

Oedema Inhibition (%) [a]			
Time (h)	PA*	Batch C	Batch F
0.5	22.1 ± 0.71	11.0 ± 1.41	11.0 ± 0.70
1	33.0 ± 1.41	22.0 ± 0.00	11.2 ± 2.12
2	44.0 ± 1.41	33.1 ± 0.70	22.0 ± 0.00
3	56.0 ± 2.12	33.0 ± 0.70	22.1 ± 1.14
4	67.0 ± 2.12	44.1 ± 0.00	33.1 ± 2.12
5	67.0 ± 0.00	56.0 ± 2.82	44.0 ± 0.70
6	67.1 ± 1.41	67.0 ± 0.00	56.0 ± 0.00
7	67.0 ± 0.00	78.1 ± 0.71 *	78.0 ± 2.12*
8	67.0 ± 0.70	78.0 ± 1.41*	78.0 ± 0.00*

Note: Results shown are mean $\pm$ standard deviation; *significantly different from the reference at $p < 0.05$; a: n = 5 animals per group. Groups PA received pure aspirin powder, Group C received Batch C formulation, while groups F received Batch F formulation. Batch C was formulated with 10% of lipid carrier and 1% w/w of aspirin, while Batch F was formulated with 15% of lipid carrier and 0.5% w/w of aspirin respectively.

Table 4.   Gastroprotective Properties of Aspirin-Loaded SLM.

Treatment Groups	Ulcer Scores	Gastroprotection (%)	Ulcer Diameter (mm)
Reference (Aspirin)	2 ± 0.707	75.00	Lesion greater than 1
Control (distilled water)	0 ± 0.00	0.00	No lesion
Batch C	0 ± 0.00	100.00*	No lesion
Batch F	0 ± 0.00	100.00*	No lesion

*Significantly different from the reference group at $p < 0.05$; Groups C and F received formulations of aspirin SLM; a: n = 5 animals per group. Batch C was formulated with 10% of lipid carrier and 1% w/w of aspirin, while Batch F was formulated with 15% of lipid carrier and 0.5% w/w of aspirin respectively.

3.7. Gastroprotective Properties

The results of the gastroprotective properties of aspirin-entrapped SLM are shown in Table **4**. The results showed absolute and complete protection of the stomach by the SLM. While the reference that received aspirin had various degrees of ulcers, pinholes, small ulcers and large ulcers, the groups that received formulations had no irritations nor pinhole. Hence, SLM could totally protect the stomach from aspirin-induced ulcers.

CONCLUSION

SLM formulations of aspirin could be a better delivery system for this drug for enhanced absorption for the treatment of inflammation and pains. The protection of the stomach mucosa from aspirin-induced irritation has been established here using SLM. Further research in the area of the inhibition of NSAID-induced ulcers using lipid-based formulations is advocated in order to facilitate the production of marketed brands of this formulation so that patients could benefit from this progress made so far.

CURRENT & FUTURE DEVELOPMENTS

Lipid-based formulation of aspirin is a novel formulation approach for aspirin, a drug that undergoes hydrolysis. This strategy has many advantages, i.e., it can enhance absorption leading to better pharmacodynamics properties compared to plain aspirin. Future strategies would aim at formulating colon targeted aspirin using modified lipid based formulations.

LIST OF ABBREVIATIONS

SLM	=	Solid Lipid Microparticles
SGF	=	Simulated Gastric Fluid
SIF	=	Simulated Intestinal Fluid
SEDDS	=	Self-Emulsifying Drug Delivery System
LC	=	Loading Capacity
LMC	=	Lipid Matrix Carrier
EE	=	Encapsulation/Entrapment Efficiency
SA	=	Stearic Acid
P90H	=	Phospholipon$^{®}$ 90H (soy lecithin hydrogenated)
S154	=	Softisan$^{®}$ 154 (completely hydrogenated palm oil)
SLN	=	Solid Lipid Nanoparticles
HGH	=	Human Growth Hormones
LBF	=	Lipid Based Formulations
COX	=	Cyclooxygenase Enzyme

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Animal Research Ethics Committee of University of Nigeria, Nsukka, Nigeria.

HUMAN AND ANIMAL RIGHTS

No humans were used. The reported experiments on animals were carried out using the guideline of use of animal in experiment by University of Nigeria Nsukka, Nigeria.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of the article is available in the repository of the University of Nigeria, Nsukka, Nigeria at URL: https://www.unn.edu.ng/nnamdi-azikiwe-library/, reference number 2011/179008.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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