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Aloe vera (*Aloe barbadensis* Miller) derived hydrocolloid; isolation, characterization and its application as a stabilizer in oil-in- water emulsions

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Abstract

One naturally occurring product that has been used in the pharmaceutical industry is the hydrocolloid. Although considerable work has been done on sourcing hydrocolloids from other sources, only few investigations have studied the possibility of obtaining hydrocolloid from Aloe vera plant, and using it as an excipient. Aloe Vera is a drought-resisting, perennial plant that belongs to the Asphodelaceae family. The purpose of this study was to extract Aloe vera hydrocolloid as a pharmaceutical excipient and evaluates its use as a stabilizer in oil-in-water emulsion. The Aloe vera hydrocolloid was precipitated out of the Aloe vera gel with methanol, and was then characterized for physical, particulate and powder properties. The Aloe vera hydrocolloid was used in concentrations of 2%, 4% and 6% w/v oil-in-water emulsions, and the stability of the emulsions was evaluated by visual observations. The particulate properties were determined using Scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR) and X-ray powder diffraction (XRD) techniques. The percent yield of the hydrocolloid was 1.12%. The SEM revealed that Aloe vera hydrocolloid consists of particles of colloidal dimensions, ranging from few nanometers to micrometers, while the FTIR spectrum of the Aloe vera hydrocolloid revealed the presence of C-H, O-H and C=O group, and the XRD showed that Aloe vera hydrocolloid is both crystalline and amorphous in nature. The powder flow properties indexes, such as flow rate, Carr's index, Hausner's ratio, and angle of repose showed the Aloe vera hydrocolloid has moderate to good flow. The high hydration capacity and swelling capacity of Aloe vera hydrocolloid was 9.4 and 900 %, respectively. The emulsions made with Aloe vera hydrocolloids had superior stablility than those made from Acacia gum.

Keywords: Aloe vera hydrocolloid, Extraction, Characterization, Stabilizer in oil-in-water emulsions, Formulation.

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Introduction

Presently, more than 80% of finished drug products and raw materials used in developing countries are imported, thus, making them expensive (Chukwu, 2001). In view of very limited financial resources, pharmaceutical industries in developing countries have recognized the need and importance of utilizing local and naturally occurring materials from economic view and possible ease of availability.

One naturally occurring product that has been used in the pharmaceutical industry is the hydrocolloid. This is because hydrocolloid and its derivatives are multifunctional excipients in drug formulations. It is against this background that some investigators (Ogaji *et al*., 2012; Emeje *et al*., 2008; Alalor *et al*., 2014; Iji *et al*., 2025, Okpanachi *et al.,* 2025) have examined plants hydrocolloids as pharmaceutical excipients. Although considerable works have been done on sourcing hydrocolloids from other sources, only few investigations have studied the possibility of obtaining hydrocolloid from Aloe vera plants and using it as a pharmaceutical excipient. Rahman *et al.,* (2016) investigated the ability of Aloe vera mucilage as solubility enhancer in tablet formulations. Alex *et al*., (2019) reviewed Aloe vera gel and its leaf extract with regards to their functional and versatile excipient properties for drug delivery, while Jani *et al.*, (2007) investigated Aloe vera mucilage for sustained released matrix tablets.

No study, to the best of our knowledge, has been done on the potential of Aloe vera hydrocolloid as a stabilizer in oil-in-water emulsion - hence, the need for this present study.

Materials and Methods

Thus, this research study aimed to assess the potential of Aloe vera hydrocolloid as a stabilizer in emulsion formulation.

Collection and Identification of Aloe vera

A fresh green Aloe vera was collected from Unguwan Idi, Gombe, Gombe State, in January 2023. The plant was identified and authenticate at the herbarium unit of the Department of Pharmacognosy, Faculty of Pharmaceutical Sciences, Gombe State University, Gombe, Nigeria.

Methods

Extraction of Aloe vera gel

The fresh Aloe vera leaves were cleaned, and using a sharp knife, the narrow side was carefully removed, the green skin was peeled off and the gel was scooped out using a spoon into a basin.

Preparation of hydrocolloid powder

The collected gel (345.5 g) was put into a large basin, and 850 mL of methanol was added to it, while stirring for 2-3 minutes. The mixture was allowed to stand overnight. The preparation was passed through a sieve to strain out the methanol. The retained residue was spread in a tray, dried in the oven for 4.0 h, and pulverized into a fine powder and stored in glass bottle (Figure 1 A-F).

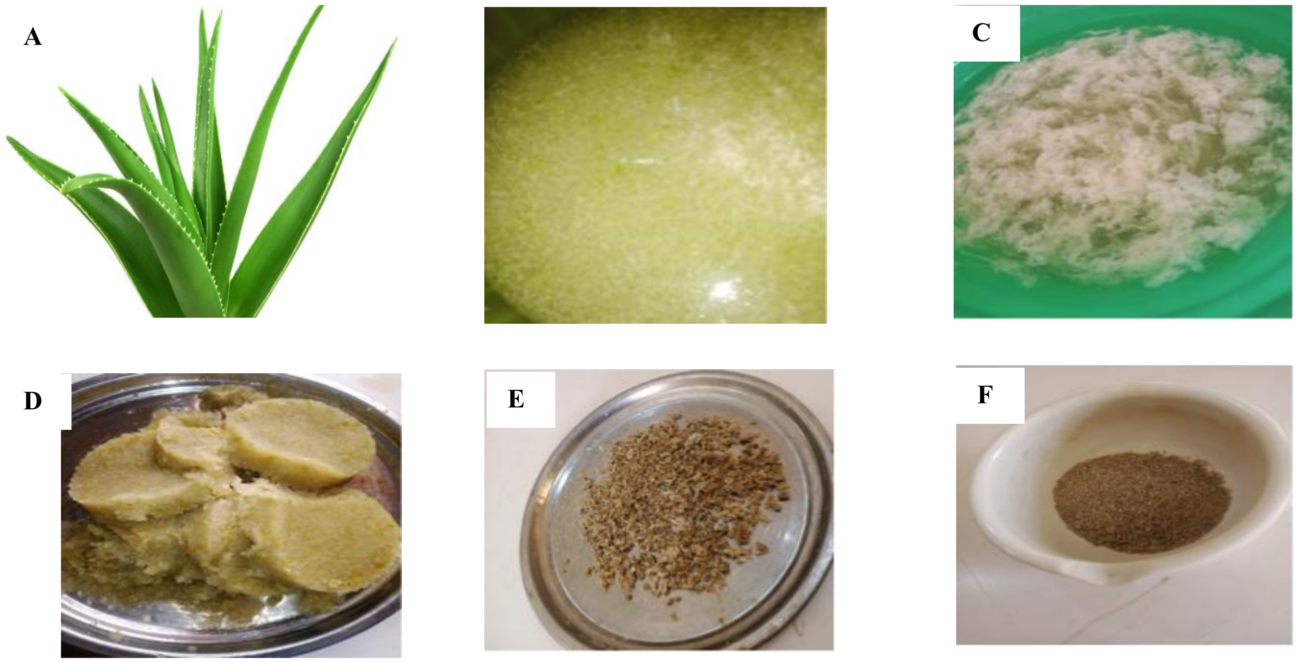

Figure 1. Process of extraction of Aloe vera hydrocolloid from Aloe vera gel; (A) Aloe vera leaves; (B) Aloe vera gel; (C) Precipitation of Aloe vera gel with methanol; (D) Precipitated Aloe vera hydrocolloid; (E). Aloe vera hydrocolloid size reduced and dried; (F) Powdered Aloe vera hydrocolloid.

Determination of percentage yield

The powder sample after drying was weighed, and the percentage yield was determined.
Physical evaluation of Aloe vera-derived hydrocolloid
The Aloe vera hydrocolloid was physically evaluated for organoleptic properties and solubility using methods reported in USP/NF (2020).

Determination of particulate structural properties

To determine the chemical functional groups, present in the Aloe vera hydrocolloid sample, the PerkinElmer Spectrum 1000 Fourier transform infrared spectrophotometer was used to scan the sample for 64 times at resolution of 4 cm^{-1} between 4000 cm^{-1} and 500 cm^{-1}.
To determine the crystallite nature of the Aloe vera hydrocolloid, an X-ray beam was focused on the sample and the intensity of scattered light as a function of the beam direction of travel measured. Cu Kα radiation at 10 Kv and 25 Ma was employed to capture the diffraction pattern. A pressure of 50 MPa was used to compress the sample.

The crystallinity index (CrI) of the sample was calculated (Segal *et al*., 1959; Ohwoavworhua and Okhamafe, 2020).

$$CrI = (I_{002} - I_{am})/I_{002}$$

Where I_{002} is the intensity of the peak (at about 2θ = 22) and I_{am} is the intensity correspond to peak at 2θ =1

For the morphological features of the Aloe vera hydrocolloid, the scanning electron microscopy (SEM) - utilizing the phenom Prox SEM model from phenom World Einhoven the Netherlands – was used. The sample was coated with 5nm of gold using a sputter coater (Quorum Technologies Model Q150R) after being placed on double adhesive that was on sample stub. After viewing through NaVCaM for focusing and minor adjustments, it was then transferred to SEM mode where it was focused and the brightness and contrast were automatically adjusted. The morphologies of various magnifications were stored in a USB stick.

Powder properties

Powder properties such as flow rate, bulk and tapped densities, true density, powder porosity, Hausner ratio, Carr's index, angle of repose, moisture content, moisture sorption capacity, hydration capacity and swelling capacity were determined as reported previously (Ohwoavworhua and Okhamafe, 2020; Oduola *et al*., 2023).

Preparation of emulsion

The wet gum method was used. Three (3) emulsions of 2 %, 4 %, and 6 % w/v concentrations were prepared using Aloe vera hydrocolloid and Acacia gum as standard emulsifying agent. Water was and added to the Acacia gum, and quickly triturated until the gum was dissolved forming mucilage. A known volume of oil was measured and added to the mucilage gradually in small portions and was triturated in one direction until a thick primary emulsion was obtained and transferred into a labeled measuring cylinder. The same method was used for the Aloe vera hydrocolloid emulsion preparations.
The stability of the emulsion was evaluated by observing the time taken for each emulsion to either break, cream or separate. Comparing both Acacia gum and Aloe vera hydrocolloid emulsions and time taken to change was recorded at 0, 1, 2 and 18 h and level of creaming was recorded as well.

Results

The percentage yield of the extracted Aloe vera hydrocolloid was 1.12%.

Physical evaluation of Aloe vera derived hydrocolloid

The hydrocolloid was observed to be off white in color with a mild pleasant smell, coarse texture and having a bitter taste (Table 1).

Table 1: Evaluation of Physical Characteristics Aloe Vera Hydrocolloid

Parameters	Characteristics
Colour	Off white
Odour	Mild pleasant odor
Taste	Bitter taste
Texture	Coarse
Form	Powder
Solubility:	
Cold water	Insoluble
Hot water	Partially Soluble

Particulate Structural Properties

The scanning electron micrograph (SEM) shows that Aloe vera hydrocolloid consists of particles of colloidal dimensions, ranging from few nanometers to micrometers (Figure 2).

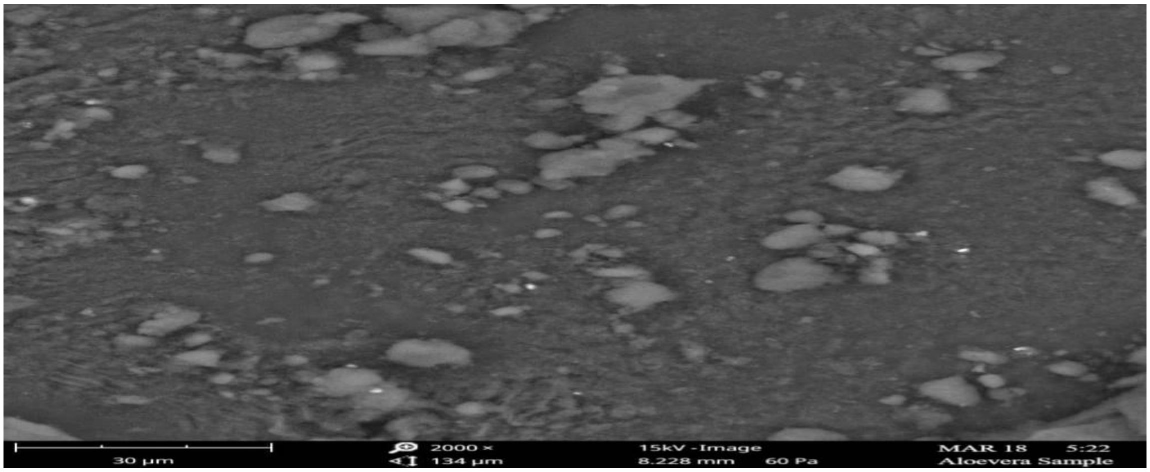

Figure 2: Scanning electron micrograph of Aloe vera hydrocolloid, revealing its morphological characteristics

The FTIR spectrum of Aloe vera hydrocolloid shows the predominant chemical groups. The peaks of interest include stretch vibrations in the 3422.61, 2923.88 cm^{-1}, 1618.04 cm^{-1} and 1384.46 cm^{-1} ranges, respectively (Figure 3). The peak in the stretch vibration of 3350 - 3450 cm^{-1} corresponds to an O-H stretch most likely from carbohydrates, proteins and polyphenol compounds; the stretch vibration of 2850- 2950 cm^{-1} is a C-H and CH_2 stretching of aliphatic group; while peak wave numbers between 1700- 1850 cm^{-1} corresponds to stretching zone of C=O (carbonyl) functional group. Thus, the Aloe vera hydrocolloid consists of C-H, O-H and C=O groups (Figure 3).

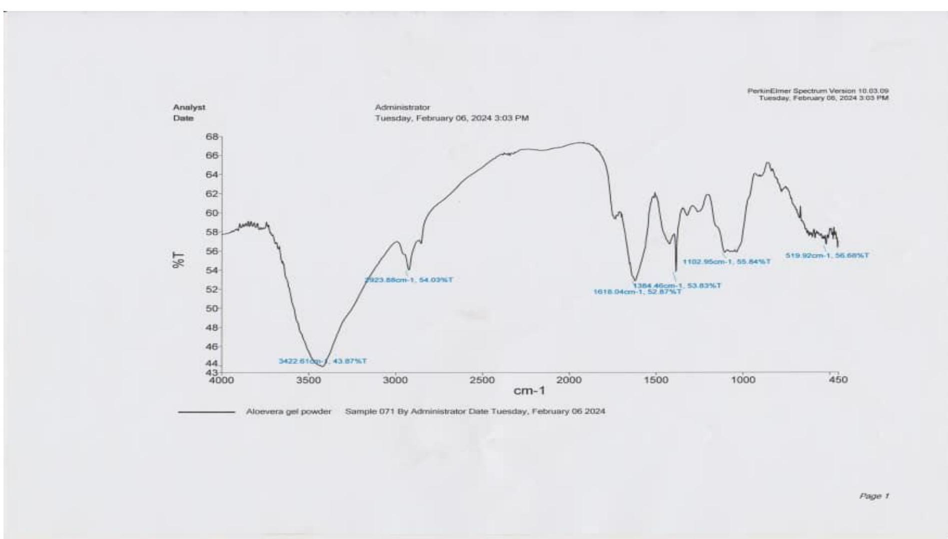

Figure 2: Fourier transform infra-red spectroscopy (FTIR) of Aloe vera-derived hydrocolloid, showing its characteristic functional groups

Figure 3 is the X-ray diffractogram of Aloe vera hydrocolloid. The three very sharp peaks at 16 °2, 22°2 and 40° 2 Theta, respectively and other broad peaks, indicate that Aloe vera hydrocolloid is both crystalline and amorphous in nature.

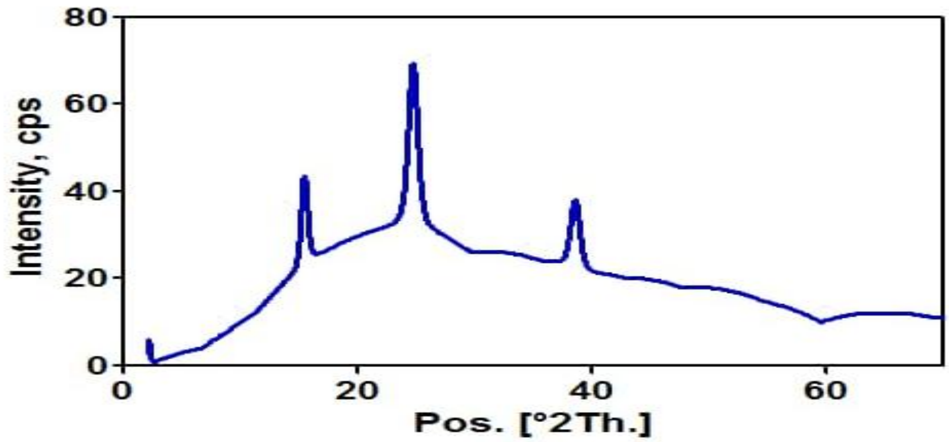

Figure 3: X-ray diffraction pattern of powdered Aloe vera hydrocolloid, showing that the material is largely crystalline in nature

Powder properties of Aloe vera hydrocolloid

The bulk and tapped densities of the Aloe vera hydrocolloid sample were 0.33 and 0.50 g/mL, respectively. The flow rate of the sample was 9.85 g/s, while the Carr's index and Hausner ratio of Aloe vera hydrocolloid were 34 % and 1.5, respectively. The moisture content of Aloe vera hydrocolloid was found to be 8 %, while the moisture sorption capacity, at the end of day three, was 90 %, and the swelling and hydration capacities of Aloe vera hydrocolloid were 900 % and 9.4, respectively (Table 2).

Table 2: Powder properties of Aloe vera hydrocolloid

Parameters	Results
Bulk Density (g/ml).	0.33
Tapped Density (g/ml).	0.50
True Density (g/ml).	1.20
Flow Rate (g/s).	9.85
Hausner Ratio.	1.5
Angle of Repose (°)	25.6
Carr’s Index (%).	34
Moisture Content (%).	8
Moisture Sorption Capacity, at the end of day 3 (%)	90
Hydration Capacity	9.4
Swelling Capacity (%).	900
Powder Porosity (%).	55.8

Stability Characteristics of Oil-In-Water Emulsions as Dispersion System

The prepared emulsion types (from Acacia gum and Aloe vera hydrocolloid, at the respective concentration of 2, 4, and 6 %) were observed closely at 0, 1, 2, 18 hours, and after shaking. Also, the emulsions were observed for changes of phase separation. It was observed that for both emulsions at all concentrations, dispersion was formed. After an hour, de-emulsification was observed for all concentrations, indicating visible phase separation of the water phase and the oil phase (Table 3).

Table 3: Stability characteristics of oil-in-water emulsions with Aloe vera hydrocolloid, and Acacia gum, as stabilizers at different concentrations

S/N	Hours	Acacia 2%	Aloe vera 2%	Acacia 4%	Aloe vera 4%	Acacia 6%	Aloe vera 6%
1	0	Dispersion formed	Dispersion formed	Dispersion formed	Dispersion formed	Dispersion formed	Dispersion formed
2	1	Demulsification (phase separation)	Demulsification	Demulsification	Demulsification	Demulsification	Demulsification
3	2	Remained demulsified	Remained demulsified	Remained demulsified	Remained demulsified	Remained demulsified	Remained demulsified
4	18	Remained demulsified	Remained demulsified	Remained demulsified	Remained demulsified	Remained demulsified	Remained demulsified
5	After Shaking	Stable	More stable	Stable	More stable	More stable	More stable

Discussion

Pharmaceutical powders are described as heterogeneous systems with different physical and chemical compositions with a range of particle sizes between a few micrometers to about a millimeter. In a typical pharmaceutical industry, more than 80 % of production is based on powders for preparation of different dosage forms. For this reason, the knowledge and subsequent control of the powders physical behavior is crucial in the development and processing of solid dosage forms (Sandel, 1983).

The low level of yield (1. 12%) is due to the composition of the Aloe vera gel, which is 98 % water (Alex et al., 2019). The bitter taste is due to the fact that Aloe vera gel contains a loin, in the middle layer, which is a bitter yellow sap. And this is in tandem with the Arabic word ‘Alloeh” or Hebrew word “Halal”, from which it earns its name, Aloe vera; and both words mean shining bitter substance (Baby and Justin, 2010).

The nanometer size particles of the Aloe vera hydrocolloid are significant for its stabilizing properties in oil-in-water emulsion formulations, as it will allow the hydrocolloid to form thin film around oil globules in the dispersion medium. The Aloe vera hydrocolloid being both crystalline and amorphous in nature is considered good, as the amorphous portion of this material allows for good drug-excipient interaction, while the crystalline nature will impact compatibility, when it is used in tablet dosage formulations. The powder flow behavior is a key factor in a series of unit processes such as blending, compression, filling, and transportation and in scale-up operations (Marshall, 1986). Also, in tablet compression and capsule filling, an optimal powder flow must be achieved in order to produce final product with an acceptable uniformity content, weight variation and physical consistence, particularly in tablet compression and capsule filling. In the drug development stage, an accurate assessment of the flow properties is essential in order to identify the optimum formulation. To evaluate the powder flow properties, parameters such as, angle of repose, compressibility index or Carr’s index, and the Hausner ratio, are generally employed. These methods are recommended by the Pharmacopeias to evaluate powder flowability, they are easy to handle and their applications are widely used in industrial applications and in scale-up operations (Sandel, 1983). The flow rate (9.85 g/s) indicates that Aloe vera hydrocolloid powder has a very good flow property. The angle of repose (25.6°) indicates good flowability. Carr (1965) and Hausner (1972) in establishing a relation between flowability of powders and some simple physical measures, reported that angles of repose below 30° indicate good flowability, while 30°- 45° shows some cohesiveness.

The higher the bulk and tapped densities, the better the potential of the powder to flow and rearrange under compression (Marshall, 1986). Bulk density is a crucial parameter in regards to the handling, storage, packaging, reconstitution, and transport of a product. Marshall (1986) stated that the porosity of powder and the number of free spaces between the particles corresponds directly to the bulk density of the final product.

Hausner ratio is indicative of interparticle friction, while Carr's index is a function of the ability of a material to diminish in volume; as the value increases, the flow of the powder decreases (Ohwoavworhua *et al*., 2005; Okpanachi *et al*., 2025). In general, Hausner ratio that is greater than 1.25 indicates poor powder flow and Carr's index below 16 % indicates good powder flowability, while values above 35 % indicates cohesiveness. Thus, on the basis of these two parameters, Aloe vera hydrocolloid would exhibit poor flow and would need a glidant to improve its flow properties.

Generally, pharmaceutical powders have moisture content within the range of 5 - 13 % (USP/NF 2020). The moisture content of 8 % fell within the acceptable range. It should be noted that moisture content plays a significant role in the stability of pharmaceutical products, as materials with higher moisture content would support bacterial growth and chemical degradation.

For swelling and hydration capacities, powders with high hydration capacity when used in tablet formulations disintegrate quickly (Ohwoavworhua *et al*., 2005). This implies that tablets made with Aloe vera hydrocolloid powder will break up faster.

Acacia gum emulsion at all concentrations, showed a clearer or more visible phase separation, compared to Aloe vera emulsions. It is explained that the de-emulsifications at all the time intervals (1, 2, 18 hours) could be due to inability of the hydrocolloid particles to form thin films around the oil globules. After shaking, it was also observed for Acacia gum, 2% and 4% showed equal stability; the 6% was however more stable, and it corresponds in stability with Aloe vera emulsions at 2 %, 4 % and 6 %, which showed more stability. This signifies that Acacia gum emulsions showed less stability when compared to Aloe vera emulsions. It appears the shaking of emulsion provided the hydrocolloid particles to form a thin film over oil globules, thus causing it to stabilize the emulsions, hence the observed considerable stability of the emulsions.

Conclusion

Aloe vera hydrocolloid was successfully extracted from the Aloe vera leaf, and precipitated with methanol overnight. The Aloe vera hydrocolloid showed better stabilizing properties than Acacia gum. Thus, the Aloe vera hydrocolloid can be used as a stabilizer in industrial pharmaceutical emulsion formulations

Based on the results obtained from the study, it is recommended that a combination of Aloe vera hydrocolloid with a suitable surfactant, such as sodium lauryl sulphate, as stabilizer be investigated in oil-in-water emulsion formulations, with a view of evaluating their combined stability properties.

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