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Enchancing sharia compliance in the halal food industry in the digital era: the role of muslim scholars, blockchain, and internet of thinsgs (IoT) technologies

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Abstract. This study aims to examine the role of muslim scholars to ensure sharia compliance in the halal food industry in the industrial era 4.0 through digital technology. The entry of the industrial revolution 4.0 which is marked by massive integration of digital technology, demands new innovations in the halal food industry. The demand for halal products in Indonesia is also increasing, but ensuring sharia compliance throughout the supply chain is a challenge in itself. The issues of revocation of halal certification by BPJH as happened in the food industry in August 2024, require the presence of new solutions. This study uses a qualitative literature study method, with data sourced from international and national journals. The results of this study indicate that muslim scholars have a crucial role in setting halal standards, issuing fatwas, and building consumer trust. On the other hand, digital technologies such as blockchain and the Internet of Things offer innovative solutions by providing a transparent, immutable, and decentralized recording system. Thus, every stage of production and distribution can be tracked in real-time, increasing transparency and accountability.

Keywords: Role of muslim scholars, halal food industry , blockchain, internet of things

INTRODUCTION

The halal food industry, as a significant segment of the global food market, is grounded in the principles of Islamic law (Sharia), which dictate strict guidelines for permissible (halal) and impermissible (haram) food production, handling, and consumption (Kurniawati & Cakravastia, 2023, p. 2). According to the index created by the Global Islamic Economy Indicator in 2023, food and fashion are halal products that have consistently experienced growth from 2021 to 2022 (State of the Global Islamic Economy Report, 2023, p. 78). With the increasing demand for halal product across diverse geographical regions, the need for enchanced Sharia compliance in food manufactoring, distribution, and certification processes has become more critical than ever.

Table 1. Halal Food Index in Islamic Economy Sector Import Growth

Year	Income US$ billion	Year	YOY (%)
2020	$260,5		
2021	$265,1	2021-2022	1,8
2022	$282,1	2022-2023	6,4

Source: SGIE report in 2023

In Indonesia, the goverment has mandated halal certification for the food industry through Law No.33 of 2014 (Menteri Hukum dan Hak Asasi Manusia, 2014), which was later revised by Law No.11 of 2020 on Job Creation (Indonesia, 2020, p. 281), with the addition of an article regarding the mandatory halal certification for micro and small enterprises. Althought this policy aims to increase Shari'a compliance in the food industry, there are still many problems in the halal certification process. Including violations that have resulted in the revocation of halal certification, as happened in August 2024 (BPJPH, 2024). This indicates the need for increased supervision and a better understanding of compliance with halal standards throughout the entire food supply chain.

On the other hand, technological advancements have been rapidly evolving. Economist have conceptualized the 4.0 industrial revolution, which signifies an era marked by the pervasive use of digital technologies in our daily routines (Xu et al., 2021, p. 532). In recent years, emerging technologies such as blockchain and Internet of Things (IoT) have demonstrated considerable potential in transforming industries by providing real-time data, enchanced security, and immutable records. These technologies are particulary relevant for the halal food industry, where ensuring the integrity of the supply chain is paramount to maintaining Sharia compliance (Rahmawati & Subardjo, 2023, p. 8).

Blockchain is a distributed public ledger or peer-to-peer network made up of "blocks" managed by a distributed network of computers, containing various verified transaction records without a central authority or third-party intermediaries (Allen, 2017, p. 1). Blockcahin facilitates transparency and data tracking, relibility and security, as weel as contract automation and verification. Additionally, this technology enables incentivization and the use of tokens (Mee San Kiu, Kai Wen Lai, Fah Choy Chia, 2022), accountability, and the automation of decision-making processes in industrial sectors (Karthik Bajar, Aditya Kamat, Saket Shanker, 2024).

In the financial world, blockchain is a distributed and centralized database system used to manage a continuously growing set of records within a company. This technology operates through a shared data infrastructure that automatically updates itself in real-time. Moreover, blockchain can complete various transactions in real time due to the application of computer algorithms. This is possible because the technology does not require a third part to verify transactions. Overall, the main advantage of blockchain is the increased transaction efficiency across various sectors within an organization, including supply chain management (Alsmadi et al., 2023, p. 1).

Due to its decentralized and transparent nature, it can offer an unprecedented level of traceability from production to consumption, ensuring that every step in the food supply chain adheres to halal standars (Hew et al., 2020, p. 3). However, additional tools are needed to implement this new technology across various sectors to ensure that the data stored in blockchain systems can be utilized, including for monitoring, auditing, and ensuring compliance (Wannenwetsch et al., 2023, p. 1313)

Similarly, IoT devices can monitor and track critical factors such as temperature, storage conditions, and certification status, providing real-time insights that enchance food safety and compliance(Taj et al., 2023, p. 1). The Internet of Thing (IoT) is a technological concept that connects various devices, enable them to activate and deactivate the web using software and automation processes for smart applications. Communication between devices can be integrated, for example, through RFID (Radio Frequency Identification) tags connected to the network to transmit identification information (Rejeb et al., 2020, p. 3).

In other terms, IoT refers to network of devices connected wirelessly (including RFID tags, sensors, actuators, and smarthpones) that frequently send data over the internet to be stored on cloud servers. Managed cloud services facilitate secure data sharing, which helps improve profability by enchancing business efficiency, speeding up decision-making, and minimizing waste and operational inefficiencies (Rejeb et al., 2021, p. 2).

Despite these technological advancements, the role of religious scholars remains indispensable. Muslim scholars, with their deep understanding of Islamis jurisprudence, are essential in interpreting Sharia law and ensuring that modern technologies align with Islamic principles (Ibrahim Fatwa Wijaya, Muhammad Agung Prabowo, Anis Widjajanto, 2024, p. 1). The integration of these scholars' expertise with cutting-edge technologies is crucial in fostering a holistic approach to Sharia compliance within the halal food industry.

Ulama also play a role in educating and guiding the community and food industry practitioners regarding the halal criteria for food that comply with the Qur'an and Hadith. A study involving 30 Muslim Scholars in Solo region of Indonesia revealed that increasing halal literacy among the younger generation is important in order to understand the concept of halal in accordance with Sharia in the future. (Ibrahim Fatwa Wijaya, Muhammad Agung Prabowo, Anis Widjajanto, 2024, p. 2) which also can be considered as one of the effective da'wah efforts in the digital era.

This study seeks to explore how the Sharia scholarship, blockchain technology, and IoT can enchance the integrity and compliance of the halal food industry. By examining the potential synergies between these elements, this research aims to address key challenges such as fraud prevention, the need for better certification systems, and the assurance of halal integrity in a globalized market. The research objectives are as follows: (1) to trace the role of Muslim scholars in ensuring Sharia compliance within the halal food products, (2) to explore the potential of blockchain and IoT technologies in improving real-time monitoring and certification compliance in halal food supply chains, (3) to propose a framework for integrating these elements into a cohesive system that strengthens halal food certifucation and customer trust.

By the evolving nature of the halal food sector and the rapid advancements in digital technologies, this research fills a crucial gap in the literature by providing a novel perspective on the intersection of Islamic jurisprudence and modern technological solutions. The findings of this study aim to offer practical insights for stakeholders in the halal food industry, including producers, certification bodies, policymakers, and consumers, to navigate the complexities of Sharia compliance in the digital age.

The literature review examines relevant works that align with the focus of this paper, specificially exploring the halal food industry and Sharia compliance, the role of Muslim scholars, and the integration of emerging technologies (blockchain and IoT) to enchance Sharia compliance compliance within the halal food industry in the digital era. By reviewing the existing literature, this paper connects previous research on these key themes to provide a comprehensive understanding of how these elements contribute to strengthening halal certification systems and ensuring ethical practices in the industry.

The Halal Food Industry and Sharia Compliance

"Halal" means "permissible" according to Islamic law. In food and beverages, halal refers to products that are allowed for Muslim consumption, which do not contain alcohol, pork, or other prohibited subtance, because these are called haram or forbidden. To compete in the global market, developing countries and non-Muslim countries need to adopt more modern technologies and production systems to produce halal food (Wahyuni et al., 2024, p. 2).

The halal food industry has witnessed significant growth in recent years, driven by the increasing Muslim population and rising global demand for halal products. As a result, ensuring Sharia compliance throghout the food supply chain has become a critical concern for both producers and consumers. Adherence to Islamic dietary laws is not only a religious obligation but also a matter of consumer trust and ethical responsibility. Research (Adekunle & Filson, 2020, p. 12) refers that strengthening the value of halal food to reduce asymmetric halal information is necessary, as consuming halal food is not just a religious obligation in Islam, but also an act of worship.

The Role of Muslim Scholars

Research (Ibrahim Fatwa Wijaya, Muhammad Agung Prabowo, Anis Widjajanto, 2024, p. 2) reveals that Muslim scholars, with their deep understanding of Islamic jurisprudence, play a private role in interpreting Sharia law and providing guidance on halal matters. They are responsible for enchancing literacy about halal food, Sharia compliance, developing halal standards, certifying halal products, and resolving disputes related to halal compliance. In the digital age, their role has evolved to include the task of adapting Islamic principles to the complexities of modern technology.

The Emergence of Technology in the Halal Food Industry

The advent of digital technologies has transformed various industries, and the halal food industry is no exception. Blockchain and IoT, in particular, offerimmense potential to enchance transparency, tracebility, and security in the halal food supply chain.

Blockchain Technology

By leveraging the decentralized and immutable nature of blockchain, it is possible to create a transparent and tamper-proof record of the entire supply chain, from the source pf raw materials to the final product. This can help to prevent fraud, counterfeiting, and mislabeling of halal products (Hew et al., 2020, p. 14). The research (Witjaksono et al., 2023, p. 2146) offers a comprehensive examination of the advantages and obtacles associated with the adoption of blockchain technology in supply chain, while also emphasizing its potential to positively influence the industry as a whole. And the research (Rahmawati & Subardjo, 2023, p. 395) recommends that policymakers implement blockchain technology in the halal supply chain system.

Internet of Things (IoT)

IoT devices can be used to monitor various parameters, such as temperature, humidity, and location, throughout the supply chain (Taj et al., 2023, p. 12). This real-time data can help to ensure that halal products are stored and transportes under appropriate conditions. The research (Rejeb et al., 2021, p. 1) offers five main benefits for the halal supply chain (HFCS) using IoT, namely: product tracebility, improved supply chaim efficiency, better livestock management, verification of product halal status, and monitoring of halal certification. And also identified several challenges including technical limitation of IoT devices, technological immatury, low user acceptance, as well as cost and regulatory barriers.

The Intersection of Sharia, Technology, and the Halal Food Industry

Research (Lubis & Fatwa Syibromalisi, 2023, p. 193) reveals that the integration of Sharia principles, Islamic jurisprudence, and advanced technologies presents a unique opportunity to create a robust and sustainable halal food industry by combining the expertise of Muslim scholars. Other researh offers that adopting the power of blockchain and IoT, it is possible to develop innovative solutions that address the challenges of ensuring halal compliance in the digital age (Wannenwetsch et al., 2023, p. 1312).

METHOD

This research employs the category of qualitative research with an exploratory approach (J.W., 2007). The focus of this research is to explore and analyze theories and findings from previous studies related to the role of scholars, blockchain technology, and IoT in enchancing Sharia compliance in the halal food industry in the digital era. The goal of this study is to investigate how technologies can strengthen halal supply chain, ensure Sharia compliance, and improve transparency and security within the halal food industry, as well as how scholars can play a role in this.

The research design is a literature review, which focuses on collecting, analyzing, and synthesizing various relevant literatures related to the research topic. This study aims to identify the relationships between different concepts and technologies that support Sharia compliance in the halal food industry. the main instrument or data used in this research is the existing literature, such as journal articles, books, and related publications. This approach allows for a comprehensive examination of existing literature on the intersection of Islamic jurisprudence, technology, and the halal food industry. the primary data source for this study is scholarly literature,

including academic articles, books, and conference papers. The researcher will utilize databases such Google Scholar, Scopus, and Web of Science to identify relevant publications, and 80% of data collected from the international journal with Scopus index.

The collected data will be analyzed using a content analysis technique, which will help identify the main themes, patterns, and relationships between the concepts found in the literature. This analysis will focus on how technology and scholars can collaborate to strengthen Sharia compliance systems in the halal food industry. This study also emphasizes research ethics by ensuring that the sources used are valid and comply with academic guidelines.

RESULTS AND DISCUSSIONS

The Role of Blockchain in Ensuring Sharia Adherence in Halal Food Production

Blockchain is a distributed public or peer-to-peer ledger consisting of 'blocks' managed by a distributed computer network containing various verified transaction records without a central authority or third-party intermediary (Allen, 2017, p. 1). Blockchain is a technology that helps in data transparency and traceability, reliability and security, as well as contract automation and verification. In addition, this technology enables the provision of incentives and the use of tokens, accountability(Mee San Kiu, Kai Wen Lai, Fah Choy Chia, 2022), applying it to the making of policies in the industrial sector automatically (Karthik Bajar, 2024).

Blockchain consists of three main components: transactions, transaction records, and a system for verifying and storing transactions. Open-source applications create blocks and record information about when and how transactions occur sequentially. Each block has a secure hash, which is generated from the index, timestamp, data in the block, and hash of the previous block. This design allows blockchain to perform audits (Muneeza & Mustapha, 2019, p. 71). After a block is verified and added to the blockchain, any changes to the block will result in a new hash that does not match the old hash and will be rejected.

In this way, every transaction is recorded in an immutable sequence, hence the name "blockchain" (block chain) reflects its function (Muneeza & Mustapha, 2019, p. 71). More specifically, Blockchain is a database system that stores transaction records with an immutable timestamp, and this data is copied to servers around the world. It can be understood from the explanation that the benefits obtained from using blockchain technology are as follows:

1. High security level: Blockchain utilizes advanced encryption technology to maintain data security. Each transaction is recorded in interconnected and encrypted blocks, making it difficult to alter or hack.
2. Decentralization: Blockchain is not controlled by a single party. Information is distributed across the network, so no one has full control. This reduces the risk of system failure and increases transparency.
3. Transparency in the process chain: Every transaction on the blockchain can be seen by all relevant parties, preventing fraud and maintaining data accuracy.
4. Time efficiency: Transaction verification on the blockchain is faster, reducing the cost and time for asset transfer.
5. Reliability: With data stored in multiple locations, blockchain is more resistant to server damage or attacks.
6. Wide range of potential uses: In addition to being used for cryptocurrencies, blockchain also has applications in various sectors such as logistics, banking, and healthcare (Dodi Setiawan, 2024, p. 312).

Internet of Things and Its Role in Supporting Sharia Compliance in the Halal Food Industry

The mechanism of the Internet of Things (IoT) in the halal certification process can be applied to monitor and ensure that the entire supply chain, from production to distribution complies with Shariah standards. IoT relies on a network of interconnected devices to collect, transfer, and analyze data in real-time. In the context of halal certification, IoT can automate monitoring and provide the necessary data to ensure that food products or ingredients remain in compliance with halal requirements (Rejeb et al., 2020). Below is the IoT mechanism that can be applied to the halal certification process:

Real-time supply chain monitoring

IoT enables highly detailed monitoring of halal product conditions throughout the supply chain, from production to distribution, through sensors and connected devices. IoT devices such as temperature and humidity sensors, can be installed in the storage and shipping conditions of halal food products to ensure that they are not exposed to conditions that violate halal pronciples (Rejeb et al., 2021).

Preventing Cross-contamination

One of biggest challenges in maintaining the halal status of food is cross-contamination with non-halal ingredients or subtances that do not comply with Shariah requirements. IoT can help reduce this risk by providing continous monitoring. IoT sensors installed along the production or storage line can detect contamination with

non-halal substance (e.g., products containing alcohol or pork). If any non-halal ingredients are detected, the IoT system can send automatic alerts (Rejeb et al., 2021). In factories or food processing facilities, IoT can be used to ensure that production procedures adhere the use of the same equipemnt for halal and non-halal products

Enchancing transparency and data security

One of the main benefits of using IoT in halal certification is its ability to provide transparency and data security. Data collected from IoT devices can be stored in secure systems, which can be accessed bt all relevant parties, including procedurs, distributors, and halal certification bodies.Data collected by IoT (such as temperature, humidity, and location) can be directly stored in the cloud or a decentralized database, which can be accessed by relevant parties (e.g., halal certification bodies). Blockchain can be integrated with IoT to ensure that stored data cannot be manipulated and remains authentic(Rejeb et al., 2021). Information collected from IoT devices can be used automatically audit the halal certification process. This reduces the need for time-consuming manual inspections and enables real-time verification of compliance.

Automation of Certification and report generation

IoT enables a more automated halal certification process, reducing the potential for human error and spending up the certification timeline. Based on data collated and verified by IoT devices (e.g., temperature or location data), the system can automatically generate halal certificates or compliance reports. These certificates can be issued directly to producers or distributors without the need for a complex manual verification process. Halal certification bodies can access data collected by IoT devices and blockchain to make data-driven decisions regarding product halal status, reducing subjectivity in assessments.

Increasing customer trust

IoT can enhance consumer confidence in halal products by providing transparency across production and distribution. Through IoT-based apps or platforms, consumers can easily access information on the halal status of products, including their production, storage, and distribution processes. Additionally, by integrating IoT with blockchain, consumers can verify that products not only have a halal certificate but also fully comply with Shariah requirements, ensuring trust and accountability(Rejeb et al., 2021).

Integration with Blockchain-Based Halal Certification Systems

The integration of IoT with blockchain enhances halal certification by ensuring data security, transparency, and integrity. IoT devices collect data (e.g., storage conditions or temperature)(Taj et al., 2023), which is stored in a decentralized blockchain ledger, making it immutable and preventing manipulation. Blockchain also enables traceability of every step in the product's journey, creating a clear audit trail to ensure compliance with Shariah standards.

Improving operational efficiency and reducing costs

Utilizing IoT in halal certification improves efficiency and reduces costs by automating processes that once required manual inspections, thus minimizing errors. Continuous monitoring through sensors during transportation and storage also decreases the need for expensive, time-consuming physical checks.

Analysis of the Integration between the Role of Scholars, Blockchain and IoT Technology according the Sharia Compliance in the Halal Industry

In the digital technology era, scholars or preachers are required to keep up with the technological developments to educate the public about Sharia principles, particularly those related to the food industry practices. Scholars must be able to develop the information systems used to connect with other preachers and enhance their knowledge about the digital advancements relevant to their preaching targets. This ensures that the preaching content aligns with the interests of the audience (Subhan, 2023, p. 37).

There are challenges in the socialization of halal certification, which remains minimal (Aliyudin, 2022), even though digital systems have been used in the process. This highlights the need for more socialization regarding the importance of certification as a means to ensure compliance with Sharia principles that should be implemented in the food and beverage industry. This requires the role of scholars who have the authority to issue halal certificates and educate the public in a more comprehensive manner. In this case, the Indonesian Ulema Council (MUI) must play a more significant role, enhanced by the support of technology in this socialization effort.

In Indonesia, there are Halal Centers established by universities and religious-based institutions with support from BPJPH, aimed at accelerating the halal certification process for products. These centers have teams of halal supervisors responsible for research, assistance, training, and monitoring halal products. Since 2019, the Halal Centers have been growing after the responsibility for halal certification was transferred from MUI to BPJPH. As a new institution, the Halal Center needs to collaborate with various entities to improve the effectiveness and reach of its work, including in remote areas, to ensure that products in these regions also receive halal certification. In addition to overseeing halal certification, these centers also serve as platforms to educate the public about the Sharia principles that must be adhered to in the halal food industry (Lubis & Fatwa Syibromalisi, 2023, p. 186)

Blockchain and IoT technology have become necessary, in addition to the guidance from scholars, for halal certification, offering high-level security and ensuring that it can be developed for maximum use. With

technological advancements, the role of scholars does not become obsolete. Instead, scholars should adapt to the existing technologies to make their preaching efforts more effective (Nurhayati et al., 2023).

In this context, the author attempts to create a concept of collaboration between blockchain technology, IoT, and Muslim scholars to increase consumer interest in halal-certified products. This would lead to a more aware society regarding the halal status of products, from the production process to when they finally reach the consumers. In its implementation, scholars play a crucial role in explaining Sharia principles to the public, who will become part of the halal supply chain. A person's compliance with Sharia principles begins with their understanding of those principles, which then require supervision and regulation by policymakers (Azifah & Fitroh, 2022, p. 116).

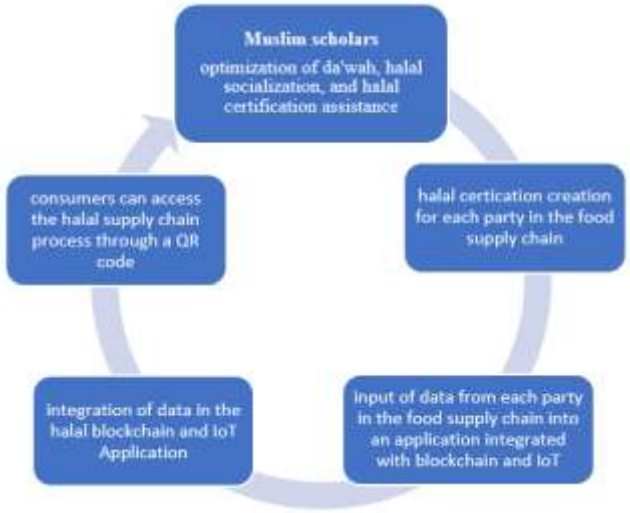

Figure 1. Supervision and Regulation by Policymakers

In the above scheme, scholars have the responsibility to educate the public about Sharia compliance in the halal industry, assist in the creation of halal certifications, and oversee and validate data on the blockchain and IoT systems to ensure it aligns with Sharia principles. Meanwhile, blockchain's role is to collect, store, and manage all information related to halal products inputted by each actor in the food supply chain. Although the entire process is automatically maintained within the blockchain, scholars must continue to oversee the production chain and conduct direct audits at certain intervals.

In the collaboration between blockchain and IoT, Blockchain functions as a digital ledger that is immutable. Every transaction or significant event in the supply chain (such as halal certification verification, raw material processing, and product shipping) is recorded transparently and permanently. This provides transparency that can be accessed by all authorized parties, including consumers, regulators, and companies.

IoT, on the other hand, provides real-time data on the physical conditions of the product during its journey through the supply chain. For example, IoT sensors can track the temperature, humidity, and storage conditions of halal products during transportation and distribution. When IoT collects data from sensors attached to the products or transport vehicles, Blockchainis used to record this data in a decentralized and immutable ledger. As a result, any changes or deviations in the product's condition can be quickly detected, and this information can be accessed by all parties involved to ensure that the product continues to meet halal standards.

Blockchain records every product or raw material with a unique identity stored on the blockchain, including details such as the origin of the material, production date, and its movement throughout the supply chain. This entire process cannot be altered, except by restarting the food supply chain from the beginning. Furthermore, when purchasing a food product, consumers can access information regarding the halal status of the product they are buying by scanning the QR code on the food or beverage packaging. In this case, potential consumers can view the detailed process of the product. If there are any doubts, consumers can ask or request a fatwa related to the product they intend to buy from scholars. Thus, the role of scholars in this concept is further optimized to address the challenges in Sharia compliance.

Furthermore, in the implementation of this concept, there are several challenges, including the fact that halal blockchain can be implemented in Indonesia under certain conditions, namely the support of government policies, new regulations related to halal blockchain technology, and the response of blockchain to the impact on the financial system, Bank Indonesia (BI), and the Financial Services Authority (OJK)(Mahsun et al., 2023, p. 230)

CONCLUSIONS

The integration of blockchain and Internet of Things (IoT) technologies into the halal food idustry holds significant potential for enchancing Shariah compliance in the digital era. These technologies provide transparent, immutable records of transactions and real time monitoring of product conditions, offering an effective means to ensure that halal products meet the strict requirements of Islamic law throughtout the entire supply chain. The involvemet of Muslim Scholars is indispensable in guiding the ethical and Shariah compliant application of these technologies, ensuring that their implementation does not conflict with Islmamic principles. By adopting blockchain and IoT technologies, the halal food industry can address key challenges such as product authenticity, traceability, and fraud prevention, while also fostering consumer confidence. These technologies can automate and secure verification processes, offering a level of accountability and reliability previously difficult to achieve in traditional supply chains. However, further research is needed to explore the full potential of these technologies in different halal food sectors, particularly in regions with varying regulatory frameworks. Additionally, further collaboration between Islamic scholars, technologists, and industry stakeholders will be essential to continuously refine and optimize these solutions, ensuring they remain aligned with both technological advancements and evolving Shariah interpretations.

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