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SMART LIVESTOCK FARMING: PRESENT STATUS, OPPORTUNITIES, AND FUTURE TRENDS

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SUMMARY

Smart livestock farming aims to achieve more productive, efficient, and sustainable farm operations based on the effective use of digital technologies. The largest potential lies in individual animal monitoring and analysis, which is referred to as precision livestock farming (PLF). Precision Livestock Farming or Smart Farming is a new take on animal farming, similar to a management change in the '80s. At this time, firms started to employ employee motivation and the concept of the 'firm as a family' in order to make better firms. PLF is an attempt at making a similar change in animal farming by detecting the needs of animals as early as possible and helping the farmers to satisfy those needs, animal wellbeing will increase. It is hoped that in turn this will increase socio-economic benefits of animal farming, i.e. make better farms.

In PLF, tools and sensors are used to continuously and automatically monitor key performance indicators of livestock in the areas of animal health, productivity, and environmental load. The ability of a computer or robot to perform tasks commonly associated with intelligent beings. It includes learning, reasoning and self-correction. It generates insights from data more quickly and accurately than humanly possible and is able to act automatically on that insight.

Internet of Things (IoT) technology is expected to play a significant role in enhancing agricultural productivity to meet feed demand. Smart agriculture incorporates IoT based advanced technologies and solutions to improve operational efficiency, maximize yield, and minimize wastage through real-time field data collection, data analysis, and deployment of control mechanism.

Diverse IoT-based applications such as variable rate technology, precision farming, smart management, and smart greenhouse will be instrumental to the enhancement of production processes. IoT can address livestock-based issues and increase the quality and quantity of livestock production, making farms more intelligent and more connected. The "Connected Farm" is the future of farming, which lies in the benefits of connecting, collecting and analyzing big data to maximize efficiency and increase productivity.

Keywords: Precision Livestock Farming, smart farming, IoT, productivity

Livestock: Importance & Challenges

Livestock are the biological transformers of low-quality feeds into high-quality protein and highly bioavailable essential minerals in diets of humans Livestock consider a key contribution to food and national security and represents a unique source of food calories (20%), protein (30%) and micronutrients. Thus, animal agriculture plays an important role in improving human nutrition, growth and health, as well as economical, political and social stability in society. Furthermore, it accounts for 40% of global agricultural gross domestic product, occupies 30% of the world`s land surface and 70% of all agricultural land and accounts for over 8% of global water use (Enahoro *et al*., 2018; FAO, 2018; FAO, 2020; Henchion *et al*., 2021).

With exponential growth of the global population and marked increases in meat consumption per capita, demands for animal-source protein are expected to increase 72% between 2013 and 2050, while Egyptian population is expected to reach 150 million by 2050 and a 60-70% increase in consumption of animal products is expected by 2050. Increases in global population and global welfare are expected to drive an increase in meat demand from 334 million tones in 2015 to 498 million tones in 2050 (FAO, 2018; FAO, 2020; Henchion *et al*., 2021)

In addition, the common challenges of livestock's are scarcity and fluctuating quantity and quality of the year-round feed supply, feed prices surge (livestock products become elite products?), low efficient use of (feed) resources, climate change (global warming), energy, and water shortages and reducing environmental footprint (FAO, 2020; Mengistu *et al*., 2021).

Strategic options for facing the challenges:

An attractive solution to meeting increasing needs for animal products and mitigating undesirable effects of agricultural practices is to enhance the efficiency of animal growth, reproduction, and lactation. Smarter production, nutrition, and waste management, as well as increased animal welfare and

better education, have the potential to decrease the impact of livestock farming on our natural resources

The applications of fourth and fifth information techniques revolution using internet of things is expected to help in achieving this goal. In addition, a promising, mechanism-based approach is to optimize the proportion and amounts of amino acids and other nutrients in diets for maximizing whole-body protein synthesis and feed efficiency. Furthermore, new management skills are required to reduce various environmental and disease-associated stresses in livestock under practical production conditions (Berckmans, 2017).

Smarter production, nutrition, and waste management, as well as increased animal welfare and better education, have the potential to decrease the impact of livestock farming on our natural resources as follow:

The best practice roll-out:

Best practices are methods or techniques that have consistently shown results superior to those achieved by other means. Large yield and productivity gaps exist across the sector, especially between industrialized and developing countries. Digitalization can make a roll-out easier, faster, and less expensive by leveraging transparent supply chains, cloud computing, improved networks, and global knowledge platforms (Andonovic *et al*., 2018).

Precision feeding:

Precision feeding can be a highly effective tool in enabling a reduction of feed intake per animal while also maximizing individual growth rates. It enables the provision of the right amount of feed, in the right nutrient composition, at the right time, and for each animal individually.

Smart waste management:

About 20% of all meat goes to waste every year. Although most waste is generated at the consumer end, the root causes lie across the whole supply chain, e.g. poor packaging or bad meat quality. Smart waste management offers high potential to first identify such root causes and second, to improve existing processes and thereby decrease waste amounts. The intelligent collection and use of data is key to understanding what is produced and what is thrown away. Through this, players along the supply chain can make focused adjustments to reduce waste at their end.

Reduced beef consumption:

In 2015, cattle accounted for over 60% of total meat livestock emissions, while beef only accounted for 20% of total meat consumption. Meat from non-ruminants such as pork and poultry produce far fewer emissions, which offers wide potential to reduce emissions by reducing the amount of beef that is consumed. Digitalization can help facilitate changes in demand patterns, e.g. by using ICT or crowd sourcing platforms to find innovative ways of communicating the benefits of dietary changes.

Thus, there is an urgent need to develop and implement Smart Livestock Systems that can make the livestock production farming systems more productive, efficient, friendly environment and sustainable (Berckmans, 2017).

What is Smart Livestock Farming?

Smart livestock farming (SLF) is an emerging concept that refers to managing farms using modern information and communication technologies to increase the quantity and quality of products while optimizing the human labor required. The SLF is the future trends and based on the philosophy that automated, continuous monitoring through technological tools enables farmers to constantly check the health and welfare status of livestock (Halachmi *et al*., 2019).

Following this idea, cameras, microphones and "smart" sensors can replace and enhance farmers' eyes and ears in everyday farming, thus making farming operations easier, more efficient, sustainable, in a win-win approach where farmers, animals and consumers can all take advantage.

Moreover, SLF is an emerging concept that refers to managing farms using technologies like **IoT**, **robotics, drones** and artificial intelligence (**AI)**. To increase the quantity and quality of products while optimizing the human labour required by production IoT is used (Halachmi *et al*., 2019). Besides there are some technologies based on IoT which are present for the farmers now a days (Tedeschi *et al*., 2021):

a) **Sensors**: Sensors for soil, water, light, humidity, temperature management.

b) Software: specialized software solutions for targeting specific farm types or use case agnostic IoT platforms.

c) Connectivity: Connecting devices like cellular, Lora, etc.

d) Location: Identifying locations with the help of GPS, Satellite, etc.

e) Robotics: Autonomous tractors, processing facilities, etc.

f) Data analytics: standalone analytics solutions, data pipelines for downstream solutions, etc.

Thus, with the help of these tools, farmers can monitor the field conditions without even going to the field and make a strategic decision for the whole farm or a single plant.

Smart livestock farming aims to achieve more productive, efficient, and sustainable farm operations based on the effective use of digital technologies. The largest potential lies in individual animal monitoring and analysis, which is referred to as precision livestock farming (PLF). In PLF, tools and sensors are used to continuously and automatically monitor key performance indicators of livestock in the areas of animal health, productivity, and environmental load (Guarino *et al*., 2017).

The internet of things or rather the internet of animals:

The Internet of Things (IoT) is a new technology that is being used to raise livestock using many applications. IoT connects the *physical world* with the *digital world*. Livestock production managers will have a better understanding of their environment. The IoT will help in predicting future events, support decision-making and improve systems. IoT can empower livestock production managers with information to track the animals health and reduce the mortality rate. IoT will alert them to how and when to intervene in feeding and caring for animals (Unold *et al*., 2020; Navarro *et al*., 2020).

How is IoT used in Farm?

The IOT allows devices across a farm to measure all kinds of data remotely and provide this information to the farmer in real time. IOT devices can gather information like soil moisture, chemical application and livestock health - as well as monitor fences vehicles and weather. The platform has an identifiable evolution in that the initial range of services can be extended to yield additional valuable information on a range of livestock traits of economic importance e.g. lameness, and the infrastructure in tandem with the solution development methodology can also be applied to yield products that address other market segments where data gathering and analysis monitoring improves the operational efficiencies (Navarro *et al*., 2020).

Benefits of an IoT enabled Livestock Monitoring system:

- To monitor grazing patterns and nutritional changes
- Track grazing animals.
- Gather and analyze historical data to identify trends in cattle health.
- Optimizing breeding practices.
- Cloud based integration and dashboard solutions to provide real time information as well as historic data to vet, nutritionists etc.

Herd management is a method to optimize health, welfare and production in a population. Animal are within a fragile ecosystem; climate change, AMR and animal welfare need to be addressed to ensure that the production system remains sustainable and resource efficient into the future (Akbar *et al*., 2020).

Smart Livestock applications:

The past 20 years have witnessed a digital revolution within agriculture. The use of automated measurement methods to monitor the behaviors of animals is becoming increasingly widespread. Software techniques have been applied to recover a range of states from the measurements including rumination, eating, standing, and lying with reasonable accuracy. These states can then be the foundation for identifying key animal conditions such as the onset of illness. The approach presents significant implementation challenges as for many IoT implementation supported by a network of low power processors and wireless data downloads. The dairy sector has increasingly adopted technological solutions to address the challenges associated with optimizing operational efficiency. The dairy cattle-focused platform elements comprise a robust, high node count sensor network with a neck mounted collar engine gathering activity data from individual animals and a cloud-based software environment that manages on farm data and pro-actively alerts the farmer, real time of key operational and management interventions (Akbar *et al*., 2020).

Smart collar unit around the neck of an animal:

An electronic unit housed in a collar around the neck of an individual animals, records individual neck and muscle movements continuously using a 3-axis accelerometer. The measured data is processed on-collar using advanced software and the data is downloaded to a PC wirelessly whenever a cow enters the receiving area of a base station, located either within the field, or within the milking parlour. Alerts indicating a particular cow condition are displayed on a local PC or on the cloud. Each collar learns normal behaviour patterns and alerts the farmer of cow conditions only when there is an indication of a high degree of confidence that intervention is required, enabling the farmer to schedule a corrective action (Figure 1). The significant differences in the variance of measured raw accelerometer data allows the derivation of various cow states e.g. rumination and eating.

In addition, one of the strongest drivers for the ready adoption of technologies within animal monitoring has been the need to optimise the fertility of dairy herds. Throughout the world, there has been a decline in cattle fertility, the reasons for which are complex and include variables such as selective breeding practices designed to optimise milk yield and other welfare factors such as reproductive diseases (e.g. metritis and ovarian cysts). Additionally, deficiencies in management practice, poor nutrition, and poor oestrus detection significantly contribute to low pregnancy rates. The imperative to improve fertility is therefore strong and while the overall herd fertility depends on a range of factors, it is widely recognised that oestrus detection is one area where a technology may have a role to play.

The signs of heat are more amenable to technological solutions that can support an automated heat detection solution, for example cows coming into heat will generally be more restless, tend to eat less and spend less time lying. Such traits can be detected using activity monitors of tri-axial accelerometer enables a rich set of information to be derived as inputs to detect not only walking behaviour (step counting) but can also yield the standing/lying budget which can be an indicator of other welfare events (Figure 1).

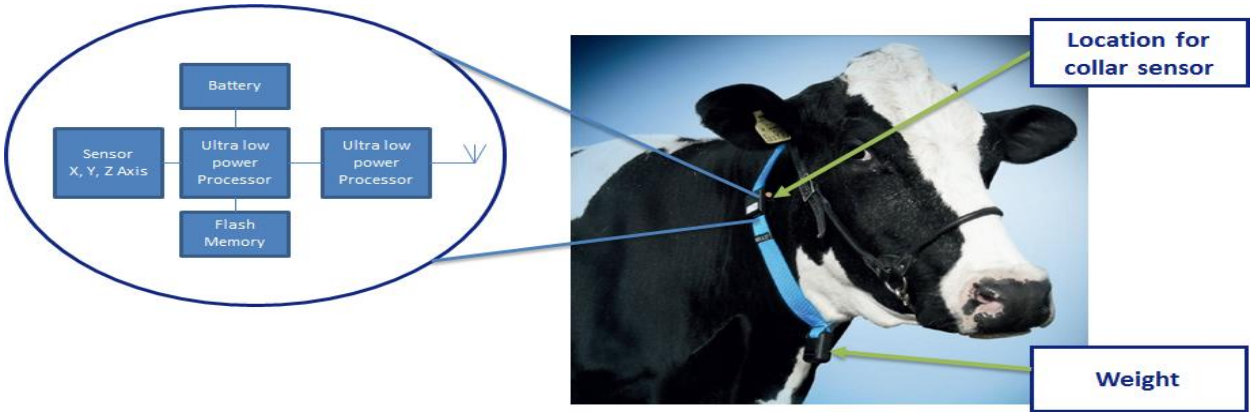

Figure 1. Smart collar unit around the neck of an animal. The unit comprises a 3-axis accelerometer, processor, low power ZigBee wireless interface and two AA batteries. The weigh ensures registration of the collar with respect to the animal's head.

Semtech LoRa. LoRa modulation basics. rev.2-05/2015 and https://www.lora-alliance.org/

Monitoring the feed intake:

Monitoring the feed intake of cattle is considered an excellent good proxy for establishing a view of overall welfare; cows that are ill will spend less time eating. Furthermore, rumination, characterized by a steady rhythmic chewing action is a key part of the digestion process; a healthy cow will ruminate for 500-600 minutes per day. The chewing activity helps maintain the ruminal pH at a level suitable for microbial activity. The, rumination is identified from the motion of the neck muscles, effectively deriving multiple signatures from the same collar. During an eating phase, the cow has to tear the feed (e.g. grass) from the ground, partially chew it and then swallow for remastication at a later time. Consequently, the muscle motions observed on the neck are considerably larger and this can be observed by the spread of acceleration measurements. This process allows the cows behaviour to be identified at any point in time using only a simple measurement of the acceleration on the neck only. An example accelerometer processed output characteristic of the rumination signature is derived from estimating the variance and the frequency content of the accelerometer measurement.

The jaw movements exhibited during eating are however, significantly larger than those during rumination. Furthermore, eating signatures are also accompanied with a wider range of head movements. The movements of the jaw during eating are less rhythmic therefore the frequency components that are present during rumination are not observed (Bloch *et al*., 2019).

A smart cow collar (COWLAR):

Smart cow collar makes life easy for the dairy staff as they can concentrate and address the important things happening on your farm. It makes life easy for the cows because they get better care, produce better & more milk and it can help farm owners improve your profit margin by up to 30%. Samrt cow collar measure the ambient, core body temperature, activity, rumination, body movement pattern, step count, gait, posture, eating behavior, comfort and lameness (Figure.2).

Figure 2. A smart cow collar (COWLAR).

A 'farm platform' for decision-making in dairy production:

The key on-farm sensor technology that will be deployed by SLF is:

1. detection of lameness because it severely reduces dairy production and is indicative of adverse welfare conditions (the cow is suffering, medicine use prevents milk utilization, and cow longevity is

decreased),
2. ambient environment because these can be used to optimize ventilation, reduce ammonia emissions and reduce energy consumption (Krpalkova *et al*., 2021).

Examples of Smart Farming Innovations:

- ***Cow sends SMS alerts to farmer:***

The Swiss start-up Anemon has developed a device that can detect when a cow is fertile and then sends out a text message to inform the farmer. A sensor is implanted in the cow's genitals to measure body heat and transmit the results to another sensor on the animal's collar that tracks body motion. The collar also features a SIM card so the farmer can pay to receive SMS alerts when the cow is ready for reproduction (Jungbluth *et al*., 2017).

- ***Transparency from farm to fork through blockchain:***

Startup Feed Blockchain XYZ has formulated a plan to create Food Supply Chain 2.0 by using blockchain. The startup hopes to tackle the six major challenges: Lack of insight, central party reliance, misleading labels, the inability for small producers to compete, supply chain opacity, and a lack of sustainability. Food Blockchain XYZ will leverage series of interconnected sensors to introduce comprehensive feed quality assurance, without the intervention of humans (Reyna *et al*., 2019; Tripoli and Schmidhuber., 2018).

- ***Fodjan smart feeding Software:***

The fodjan smart feeding software, which enables farmers to work out the right ration's ingredients. Several feeding goals are taken into account, including cost savings and animal health. For planning purposes, the software makes it possible to set up animal- based feeding calendars and check out the respective stocks of feed. Besides all the feed-related features, "fodjan smart feeding" also helps farmers to manage their farms more efficiently (Tripoli and Schmidhuber., 2018).

- ***Small device determines vitamin deficiencies:***

"Vitameter", by the Canadian start-up of the same name, is a simple blood test that allows users to check themselves regularly for vitamin deficiencies. They take a drop of blood and test it in the device. The "Vitameter" then determines the concentration of all standard and important nutrients in the blood. If needed, users can then target deficiencies with supplements. "Vitameter" is particularly useful for vegans or people with feed intolerances who are unable to feed themselves optimally, as it saves them from doctors' visits. The device is about to enter beta testing.

- ***Robot tends and guides cattle herds:***

Scientists at the Australian Centre for Field Robotics at the University of Sydney have developed a robot named "SwagBot" which is designed to help cattle breeders in the Australian outback. According to the results of a pilot test on a farm, the robot is able to herd cattle independently, clear weeds, and pull heavy loads. The robot will be developed to also be able to check the health of cattle by using sensors to analyse body temperature and movement (John *et al*., 2019).

Tracking livestock's movement with GPS:

Tracking your animals' behavior and keeping an eye on the locations wherever they go is essential nowadays. With the livestock monitoring system, you can track your livestock location. You can also locate the lost animal and rescue them in no time. The system comes with an integrated GPS tracker and geofencing feature by which it becomes easier to create grazing boundaries for the cow and other farm animals (Krpalkova *et al*., 2021).

Tracking livestock Health:

The livestock monitoring system helps in keeping a check on the health of the livestock. You can monitor the grazing pattern and make better decisions for livestock weight, food timings, etc. If livestock gets any illness such as lameness, then the medicine timings and behavior can be tracked along with the calving, lactation period, etc. With proper feed and better digestion, livestock can produce more nutritious milk (Krpalkova *et al*., 2021).

Decrease livestock Mortality Rate:

With the livestock monitoring system, you can track your livestock's eating habits and give them good feed for better produce. Also, if farm animals are suffering from disease, illness can be diagnosed and treated before it's too late. This way, the monitoring system helps in reducing the livestock mortality rate (Krpalkova *et al*., 2021).

Improved Pasture Management:

The Monitoring system for livestock can be useful for improving the pasture or grass which animals eat. Farmers can track the animal's movement and the area they are grazing. This way, animals will eat good grass and we can get better products from them. It will increase the profit which farmers earn from livestock. IoT has changed the way the livestock industry operates (Bonneau *et al*., 2020).

Cattle Health: Fertility- Pregnancy & Calving:

Cows have a limited time period in which they are fertile. This period can be as little as 8–9 hours a month. IoT Sensor is used to detect the fertility period for cattle, and ensures that this critical window of fertility is accounted for each cow in the herd. Also Detecting cow's pregnancy and monitoring the calving process help in promoting safer and more successful outcomes and eliminates the continuous supervision to check whether calving has started or not. This information can be collected automatically about each cow and sent through the internet to the farmer mobile/tablet device. In the recent researches Biosensors are playing a great rule in detecting animal disease such as Mastitis, ovarian cysts,

lameness, apparatus and hormone levels like progesterone (Berckmans, 2017).

Main Obstacles to SLF Adoptions:

Regardless of the different technologies applied, there are several obstacles and constraints have been reported on the application of SLF (Krpalkova *et al*., 2021; Aquilani *et al*., 2022) as follow:

- Lack of direct cooperation between engineers, biologists, economists and farmers
- Marketing of PLF/Smart Farming
- Too much focus on sensing and too little on interpretation and control
- Lack of a service sector with suitable business models
- Technology aversion of consumers as a result of too large a distance between consumers and modern livestock farming
- Consistent value-creation models on farm and in the feed-animal food supply chain
- Awareness and education

Future Trends of SLF:

- ✓ The success recorded with the use of IoT-based digital contact tracing capability during the current COVID-19 era to contain its spreads and also alert individuals of possible exposure highlighted two facts:
- ✓ Firstly, that it is now possible to use IoT-enabled devices to monitor infectious diseases.
- ✓ Secondly, that the technology to drive IoT for sundry management purposes in domains that are interested in the use of IoT is here and advanced.
- ✓ The future for IoT in LsM is that will require technologically advanced tools for communications, sensing, and computation.

CONCLUSION

- ➢ The research presented different IoT based technologies for farmers to manage livestock, day to day smartly.
- ➢ Nowadays, we can find IoT devices and applications in almost sectors of the livestock accurately and efficiently
- Automation and robotics, leading to 'Smart farming' can solve many of the problems facing the livestock
- Worldwide implementation of PLF needs a collaboration model between engineers, biologists, economists, industry, farmers and stakeholders**.**

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مزارع الإنتاج الحيواني الذكية: الوضع الحالي والفرص والتوجهات المستقبلية

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تهدف مزراع الإنتاج الحيواني الذكية إلى تحقيق إجراءات مزرعية أكثر إنتاجية، كفاءة واستدامة معتمدة على أساس الاستخدام الفعال للتكنولوجيا الرقمية. تكمن أعظم الإمكانات في مزارع الإنتاج الحيواني المنضبطة في المراقبة الفردية للحيوانات وتحليلها. مزارع الإنتاج الحيوانى المنضبطة أو مزارع الإنتاج الحيواني الذكية هي طريقة جديدة مبتكرة في المزارع على غرار التغيير الحادث في الثمانينيات في إدارة المزارع. في هذا الوقت، بدأت الشركات في دفع وتحفيز العاملين من خلال مفهوم الشركة كالعائلة من أجل إنشاء شركات أفضل مزارع الإنتاج الحيواني المنضبطة هي محاولة لإجراء تغيير مشابه في مزارع الإنتاج الحيوانى فى تربية الحيوانات من خلال الكشف عن احتياجات الحيوانات في أقرب وقت ممكن ومساعدة المزارعين على تلبية هذه الاحتياجات، مما يؤدى لزيادة رفاهية الحيوانات. ومن المأمول أن يؤدي هذا بدوره إلى زيادة الفوائد الاجتماعية والاقتصادية بمزارع الإنتاج الحيواني، أي إنشاء مزارع أفضل.

تُستخدم الأدوات وأجهزة الاستشعار للرصد المستمر والتلقائي لمؤشرات الأداء الرئيسية للثروة الحيوانية في مجالات صحة الحيوان والإنتاجية والإجهاد البيئي .حيث أن قدرة الكمبيوتر أو الروبوت على أداء المهام مرتبطة عادة بالكائنات الذكية .ويشمل التعلم والاستدلال والتصحيح الذاتي . وهذا يولد رؤى من البيانات بشكل أسرع وأكثر دقة مما هو ممكن عمله بشريًا ويمكن إنجازه تلقائيًا بناءًا على تلك الرؤى.

من المتوقع أن تلعب تقنية إنترنت الأشياء دورًا مهمًا في تعزيز وزيادة الإنتاجية الزراعية لتلبية الطلب على الأعلاف. تشتمل الزراعة الذكية على تقنيات وحلول متقدمة قائمة على إنترنت الأشياء لتحسين الكفاءة التشغيلية وزيادة العائد وتقليل الفاقد من خلال جمع البيانات الحقلية في الوقت المناسب وتحليل البيانات وسرعة تطبيق آلية التحكم.

يعتمد إنترنت الأشياء على تطبيقات مثل معدل التكنولوجيا المتغير، المزارع المنضبطة، الإدارة الذكية والصوب الزراعية الذكية المفيدة في تعزيز عمليات الإنتاج. يمكن لإنترنت الأشياء معالجة مشاكل مزارع الإنتاج الحيوانى وزيادة جودة وكمية المنتجات الحيوانية، مما يجعل المزارع أكثر ذكاءً وأكثر إتصالاً. "المزارع الذكية" هي مستقبل الزراعة، والتي تكمن فوائدها فى ربط البيانات الضخمة وجمعها وتحليلها لتحقيق أقصى قدر من الكفاءة وزيادة الإنتاجية.