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Sustainable food alternative in gastronomy: edible insects (entomophagy)

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Abstract
The increase in the world population, the inefficient use of resources and the constant change in living conditions constitute the problems of our age. Besides all these, the sustainability of food resources is gaining more importance day by day due to problems such as climate changes and insufficient agricultural areas. In the future, especially meeting the protein requirement is foreseen as a fundamental problem. Edible insects are considered as sustainable food sources due to the advantages in their production when compared to traditional protein sources. It is predicted that the way of eating and drinking will change in the coming years due to problems such as population growth, climate change and food crises. A literature review was conducted in this study on gastronomy trends, etymology and historical development of entomophagy, edible insects as a sustainable food alternative, the advantages of edible insects, and insect cultivation and consumption in the world and in Turkey.

Keywords
Sustainable food, Edible Insects, Entomophagy, Gastronomy, Food trends, Nutritive value

Introduction

The inadequacy of the resources to meet the food needs of the increasing world population, the inability of the people to use food efficiently and the constant change in living conditions bring humanity face to face with some problems. The most important of these problems is the difficulties experienced in accessing food. Human nutrition has been affected by the world food crisis that emerged in 2007-2008. Due to this crisis, there was a great increase in food prices, a global crisis was experienced, and political and economic instability affected all countries negatively (Gürlük and Turan, 2008). Apart from these, the sustainability of food resources is gaining more importance day by day due to problems such as climate changes and insufficient agricultural areas. Especially meeting the protein requirement is foreseen as a fundamental problem in the future. Edible insects are considered as sustainable food sources due to the advantages in their production when compared to traditional protein sources. Edible insects, which are traditionally consumed frequently in countries such as South American countries or Asia, are not accepted in western societies in terms of causing disgust (Erdoğan, Görür, Peksever, Sümer and El, 2021).

Aim and sources

The purpose of this study is, in the future, meeting the protein requirement is foreseen as a main problem. Edible insects are considered as sustainable food sources due to the advantages in their production when compared to traditional protein sources. In the study, a literature review was conducted on etymology and historical development of entomophagy, gastronomy trends, edible insects as a sustainable food alternative. Furthermore, a review of the advantages of edible insects, and insect cultivation and consumption has been carried out.

Gastronomy trends

Gastronomy is a multi-faceted discipline that concerns nations and communities, contributes to human nutrition with raw materials, creativity, traditions, different techniques and recipes, and can develop with new technologies from the perspective of the historical development of human nutrition. Gastronomy trends are affected by many factors. Trends emerge as the types of foods, the materials used in food preparation and cooking, the way food is prepared and cooked, its service and marketing. Considering this situation, it is necessary to develop a different perspective to examine gastronomy trends. It would be appropriate to associate gastronomy trends with the type of innovation that constitutes its source with this new perspective. On the other hand, it will be possible to determine the sources of the innovation motivation of the gastronomy ecosystem by examining the gastronomic trends depending on the innovation type in question and to make a mutual comparison of the trends in these innovation areas.

Eating and drinking, which is accepted as a sociological phenomenon, has paved the way for eating out to become a culture due to reasons such as not having enough time to cook, leisure time or business trips (Yıldız and Yılmaz, 2020). This change in eating habits has revealed many different trends in the field of gastronomy. Some of these flows can be seen in Table 1. The edible insects, one of the gastronomy trends, will be examined in this study. This change in eating habits has revealed many different trends in the field of gastronomy. Some of these flows can be seen in Table 1. In the study, edible insects, one of the gastronomy trends, will be examined.

Table 1. Some gastronomy trends

1.	Entomophagy/edible insects
2.	Edible flowers
3.	Fusion cuisine
4.	Functional foods
5.	Raw food
6.	Molecular gastronomy
7.	Fast food
8.	Slow food
9.	Surf & Turf
10.	Green restaurants
11.	Vegetarian cuisine
12.	Gluten free diet
13.	Blood type diets
14.	Authentic, black, and purple foods
15.	Local cuisine
16.	Neurogastronomy
17.	Organic farming
18.	Vertical farming
19.	Cellular agriculture
20.	Clean supreme
21.	Hyper-local sourcing
22.	Silicon valley & food
23.	Fast casual, Fast casual 2.0
24.	3D printed food
25.	Theme restaurants

Source: (Kurgun, 2017; Nizamlıoğlu, 2018; Oğan, 2021)

Etymology and historical development of entomophagy

Looking at the etymology of the word "Entomophagy", which is derived from Greek, "Entomo" means insect, "Phagein" means food, and the combination of these two words means "insect eating" (Pal and Roy, 2014). The use of insects as a food source has existed for centuries. Humans have been collecting and consuming eggs, larvae, pupae, and adults of some insect species from nature for many years.

We see in cave drawings and other records of ancient civilizations that people have been consuming insects for centuries. Insects have also been used in medicine, religious rituals and for nutritional purposes in the historical process (Ramos-Elorduy, 1998). It is seen that locusts strung on skewers were served at royal banquets until the 8th century BC in the Middle East (Van Huis, Van İtterbeeck, Klunder, Mertens, Halloran, Muir, and Vantomme, 2013). Eating cicadas was considered graceful in Greece, and Ethiopians were called locust eaters by Sicilians. Cossus, the longhorn beetle, which is the larva of Cerambyx cordo living in oak trees, was considered a favorite food by the Romans. Materia Medica is a book on Chinese medicine written by Li Shizhen and contains information on the use of many insects as food (Van Huis et al., 2013).

Parallel to the increasing population in the world in recent years, insects are on the agenda as an alternative food source because the demand for animal protein has not increased enough, but the production has not increased sufficiently (Güneş, Sormaz, and Nizamlıoğlu, 2017). Along with the increasing population growth, factors such as food waste, lack of awareness about nutrition, not giving the necessary importance to agriculture and animal husbandry, domestic waste and migration also affect the nutrition model of societies. For this reason, people are trying to reach many alternative new food sources in order to access sustainable and safe foods. Insects appear as an alternative food source in this context (Becker, 2007; Post, 2012; Van Der Spiegel, Noordam and Van Der Fels-Klerx, 2013; Van Huis, 2015; Karaman, 2019).

The use of insects as food has increased especially after the 2000s and has been the subject of many fields from food festivals to international conferences, and from documentaries to film festivals (Güneş, Sormaz, and Nizamlıoğlu, 2017). In his article titled "Future foods: what will we be eating in 20 years' time?" in BBC NEWS Magazine, Winterman (2012) interpreted the characteristics of entomophagy as a kind of win-win relationship. Edible insects are considered an important trend in terms of being the food of the future as a sustainable environment and food alternative for all humanity.

Edible insects also have environmental benefits with their features such as less harmful gas emission and less land requirement and economic benefits due to their low technology requirements and low capital investment. Although insect consumption is mostly seen in Asian countries, it is thought that its consumption will increase globally with the decreasing world resources over time (Kurgun, 2017).

Insects, which offer many advantages as food, are very rich in protein, vitamins, and minerals. The use of insects as food is thought to have less negative impact on the environment. This situation creates positive psychological feelings on people as the consumption of insects as food causes less damage to the environment compared to traditional livestock farming. Insects, which are considered as food, can either be collected from their natural habitats or grown in insect farms. Employment in rural areas is increasing in both of these methods. (Hanboonsong, Jamjanya, and Durst, 2013).

Considering today's conditions, it is seen that insect consumption is widespread in many countries in the world. Insect consumption becoming more common means that many restaurants include insects on their menus, thus bringing people closer to consumption of them (Baker, Shin, and Kim, 2016). Table 2 shows the edible insect species in the world and the numbers of these insect species (Ramos-Elorduy, 2005):

Table 2. Edible insect species and numbers of these species in the world

Order	Common name	No. of species
Thysanura	Silverfish	1
Anoplura	Sucking lice	3
Ephemeroptera	Mayflies	19
Odonata	Dragonflies	29
Orthoptera	Grasshoppers, crickets, and cockroaches	267
Isoptera	Termites	61
Hemiptera	True bugs	102
Homoptera	Cicada and leafhopper, mealybugs	78
Neuroptera	Net-winged insects, dobsonflies	5
Lepidoptera	Butterflies and moths	253
Trichoptera	Caddisflies	10
Diptera	Flies and mosquitoes	34
Coleoptera	Beetles	468
Hymenoptera	Bees, ants, wasps	351
Total		1681

Source: (Ramos-Elorduy, 2005)

As seen in Table 2, Ramos and Elorduy (2005) recorded 1681 edible insect species in their study. It is seen that this number is 2111 in the 'List of edible insect species of the world' published by Jongema (2017). Figure 1 shows the registered edible insect species by country:

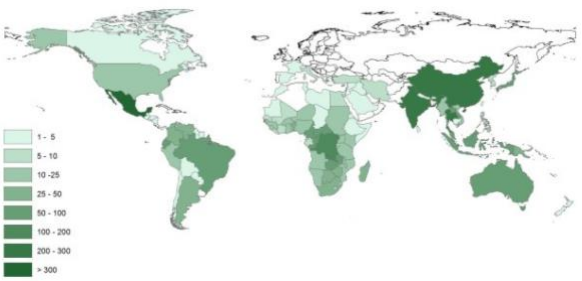

Figure 1. Registered edible insect species by country

Looking at Figure 1, it is thought that the most edible insect species are found in Asia, while there are 5-10 edible insect species in Europe and Turkey.

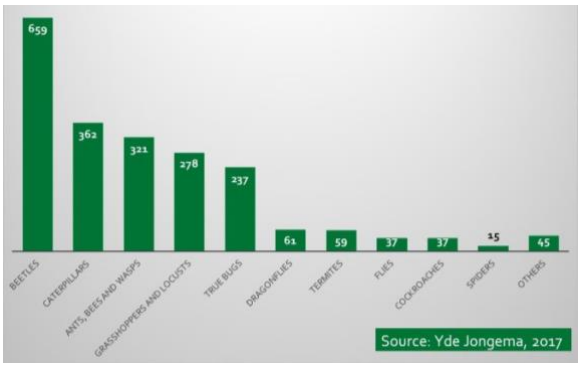

Figure 2. Grouping of edible insect species recorded in the world

When Figure 2 is examined, there are 2111 edible insect species that are most consumed and registered. The numbers of these insect species are as follows, respectively: beetles (659), caterpillars (362), ants, honeybees, and wasps (321), grasshoppers (278), hemipteras (237), dragonflies (61), termites (59), flies (37), cockroaches (37), spiders (15) and other insect species (45). Although the types of edible insects vary according to the regions, the most frequently consumed insect species are listed as mealworms, cockroaches, grasshoppers, crickets, ants, butterflies, moths, and flies. (FAO, 2013).

Edible insects as a sustainable food alternative

It is very important for sustainability that insects produce less greenhouse gases and consume less water compared to other animals. It is considered an advantage that they need smaller areas for their breeding and maintenance than another animal husbandry. Insects have both economic advantage and feed conversion efficiency by obtaining their feed from industrial by-products and agricultural residues (Baş Aksoy, and El, 2021). It is known that the feed conversion efficiency of crickets (Acheta domesticus) is 12 times higher than cattle, 4 times higher than pigs and 2 times higher than chickens (Van Huis et al., 2013). Most insects use unsuitable plant material as nutrients for agricultural by-products. Therefore, insects do not play a negative role in the consumption of food sources compared to cows, chickens and pigs that consume human food (Dossey, Tatum, and McGill, 2016; Baş Aksoy, and El, 2021). Studies have shown that while 25 kilograms of feed is spent to produce 1 kilogram of beef, 2 kilograms of feed is spent to produce 1 kilogram of edible insects (Guine, Correia, Coelh, and Costa, 2021).

While few people consumed snails, shrimp, crab, lobster, frog legs and raw fish in the early 1980s, many people today consume such products in a variety of ways. The term 'new sushi' is also used for the increasing trend towards edible insects in recent years. For example, some of the raw fish consumption patterns can be listed as follows (Uzun, 2017):

- *Sushi:* It is a traditional Japanese dish in which cooked vinegared rice and various ingredients are served on or inside raw fish such as seafood, vegetables.

- *Sashimi:* It is another Japanese dish consisting of thinly sliced raw fish or meat.

- *Poke:* It is a Hawaiian salad made with pieces of raw fish mixed with spices and vegetables.

- *Ceviche (Seviche):* It is a traditional Peruvian dish that is served cold and is marinated by chopping large fish with white meat, the bones of which can be easily removed, and by keeping them in lime or lemon juice (citric acid) for 2-3 hours in a glass bowl.

- *Gravlax:* It is a Scandinavian dish made by marinating raw salmon with sugar, salt and dill. It is consumed with mustard sauce.

- *Koi Pla:* It is a Southeast Asian dish made by mixing finely chopped fish with lime juice, fish sauce, herbs, and vegetables.

Considering the examples given above, the fact that people who used to refuse to eat raw fish consume raw fish frequently in different ways supports that this situation may one day be valid for insects as well. In his study, Shapla (2012) describes his amazement when he saw that children were playing with their friends in the garden, excitedly consuming ants and saying that it was a very tasty thing. The fact that 2 billion people around the world eat insects today shows that this situation should not be surprising.

Advantages of Edible Insects

The entomophagy movement, which is described as a strong solution for climate challenges and health, is becoming widespread day by day (Müller, Evans, Pane, and Roberts, 2016). Narzari and Sarmah (2015) emphasize that the widespread use of insects as a natural resource is necessary. It is predicted that edible insects will play an important role in tackling a possible food crisis or depletion of natural resources. Their superiority in nutrition is effective in the inclusion of edible insects in the menus and their being considered as attractive elements as food (Kurgun, 2017).

The nutritional advantages of edible insects are: they are good sources of protein, they contain more calcium than milk, they contain 20 times more B12 than steak, saturated fat ratios in insects are quite low, magnesium content of insects is 5 times higher than steak, they are rich in beneficial probiotics that are beneficial for the intestines, they contain 9 essential amino acids that provide repair and development of muscles, they do not contain GMOs, chemicals, and sugar, they are rich in chitin, which provides support in the fight against tumors, viruses, and allergies, they contain more iron than spinach and they do not include animal-borne diseases transmitted to humans.

Scientific research on the reasons for the preference of edible insects still continues today. It is seen that there is a need to develop new processing methods or take precautions in order to deepen the researches on some of these advantages mentioned above and to eliminate the problems such as animal-based diseases transmitted to humans. For this purpose, it should be carried out in a transparent manner, taking into account the guidance of the scientific research results of the necessary legal regulations within the framework of the producer, processor, and consumer. Such studies will be able to transform edible insects into a safe and natural gastronomic ecosystem food (Kurgun, 2017).

In the study titled "Edible Insects: Future Food and Feed Safety Perspectives" published by the United Nations Food and Agriculture Organization (FAO) in 2013, 3 main reasons for consuming insects are mentioned (Van Huis, Van Itterbeeck, Klunder, Mertens, Halloran, Muir, and Vantomme, 2013; Kurgun, 2017):

Health

- Insects are healthier and more nutritious alternatives to pork, beef, fish, and chicken.

- Most insects are very rich in calcium, good fats, iron, zinc, and protein.

- Insects are a traditional part of many regional and national diets.

Environment

- While growing edible insects is not a land-based activity, there is no need to expand land to expand production.

- Edible insects emit less greenhouse gases than many animals. For example, methane gas is produced by several groups of insects, such as cockroaches and termites.

- Because insects are cold-blooded, they are more successful at converting food into protein. For example, crickets need to eat 12 times less than cattle, 4 times less than sheep and half as much as pigs and chickens to produce the same amount of protein.

- Edible insects can also feed on organic waste.

- Consumption of insects as food is also a healthy and safe way to help reduce insects without the need to use pesticides (Holland, 2013).

Livelihood (Social and Economic Factors)

- Edible insect farming (mini livestock) provides a livelihood in both urban and rural areas.

- The edible insect farming business is a low-tech and capital investment option. It provides the opportunity to participate in the economy even in the poorest sections of the society.

In addition to the negative effects of land and water use, climate change and increasing world population, new strategies should be developed in malnutrition and food production. It is predicted that edible insect cultivation will contribute significantly to the solution of hunger in a sustainable environment (Nadeu, Nadeu, Franklin, and Dunkel, 2014).

Insect breeding and insect consumption in the world and in Turkey

In recent years, interest in edible insects, especially crickets, has increased considerably in Western countries. More than 30 edible insect companies were established in North America in 2012. Edible insect production and its integration into the gastronomic ecosystem have been progressing and developing effectively in recent years (Kurgun, 2017). Thailand is one of the important countries in insect farming and 7500 tons of edible insects are produced annually in 20 thousand farms (Hanboonsong, Jamjanya, and Durst, 2013; Karaman, 2019).

In order to promote insect breeding, an international project is carried out in Africa, especially on crickets. Insect farming in the West is mainly for the purpose of supplying pet food, and in some countries this situation varies. For example, special production areas for crickets, grasshoppers and mealworms have been

established by some companies in the Netherlands for human consumption (Van Huis, 2015; Karaman, 2019).

There are businesses and farms producing edible insects in many countries around the world. Some of these businesses are listed in Table 3 (Kurgun, 2017):

Table 3. Edible insect producing businesses and farms in the world

Business/farm	Country
Jimini's	France
Snack İnsect	Germany
Beetle Jelly	Belgium
Gran Mitla	Mexico
Exa Foods	Canada
Edible Bug Farm	UK
Edible Bug Shop	Australia
Entomos	Switzerland
Chapul	USA
Bugsolutely	Thailand
Primal Future	New Zealand
Haocheng	China
Insektenessen	Austria
ArhtroFood	Colombia
EntoCube	Finland
Livin Farms	Hong Kong
Big Cricket Farms	USA
Nutrinsecta	Brasil
Ento Factory	Chile
Nutrition Technologies	Vietnam
Mira Livestock Insect	Turkey

Source: Kurgun, O. A. (2017)

As can be seen in Table 3, there is a facility for insect breeding in Turkey. Although the Mira Livestock Insect Farm in Antalya currently produces insects as animal feed, they deliver the insects live to their customers when an order is placed for human consumption. Insects such as mealworms, grasshoppers and crickets are produced in this farm (Karaman, 2019). There is no detailed scientific study on insect consumption in Turkey. Considering the production amount of mollusks and crustaceans in Turkey between 1985 and 2005, the main mollusks are listed as Mediterranean mussel, octopus, sea snail, sand mussel, hairy mussel, cuttlefish, stone mussel. Crustaceans can be listed as lobster, crab, crayfish, shrimp, and some insect species. While insect production was 47 tons in 1985, it was determined that this amount decreased to 30 tons in 2005 (Başçınar, 2007; Mankan, 2017; Karaman, 2019).

Some examples of the use of edible insects in the kitchen

In Karaman's (2019) thesis study, the preparation stages of food or beverages to be made with edible insects were mentioned. It was mentioned that insects should be washed before use, and that the pheromones responsible for the taste and odor of insects will disappear due to washing. It has been said that after the washing phase, their flavor can be increased with various seasonings and spices. Insects such as grasshoppers should not be fed for 12 hours before being consumed because insects can also feed on bitter plants. Since the bitter taste passing through such plants also affects insects, it takes time for the insects to get rid of this bitterness from their digestive systems. In addition, edible insects should be kept in the freezer for 15 minutes before being prepared for consumption, and their vital functions should be expected to end. It is known that if the insects are left in the freezer for more than 15 minutes, the insects will freeze and there will be negative changes in the taste of the insects thanks to freezing. In Oaklander's (2015) article titled "20 Delicious Bug Recipes from Chefs" published in the Times, various restaurants in different states of America were researched and 20 recipes made with edible insects were exemplified. Some of these recipes can be listed as follows:

Chef Karen Barroso's Garlicky Grasshopper Mix

There are 398 different species of edible insects in Mexico. Grasshoppers or chapulins (a type of locust native to Mexico) are among the most commonly consumed insects. Chef Karen Borroso cooks the garlicky grasshopper while she prepares the chapulins by sautéing them with garlic, cloves, Chili de Arbol hot pepper oil, sea salt, and Spanish peanuts. It is then served at the bar, accompanied by Mezcal (a Mexican high-alcohol drink made from the sap of the agave plant grown in Mexico - Karen Barroso, Guajillo, Arlington, Virginia (Oaklander, 2015).

Figure 3. Chef Karen Barroso's Garlicky Grasshopper Mix

Chef Laurent Quenioux's Ant Larvae

Blini (mini pancakes) are made with ant larvae (escamole), quail eggs and salmon eggs. Later, when the eggs are frozen, the meringue is made with albumen (egg white), which flows out. They serve Mexican tea leaf (epazote), ant larva (escamole), serrano pepper and shallot on a nasturtium leaf, sautéed in butter, and served on a corn tortilla accompanied by Mexican beer and lime gel (Laurent Quenioux, Bistro LQ, Los Angeles (Oaklander, 2015).

Figure 4. Chef Laurent Quenioux's Ant Larvae

Chef Zack Lemann's Lightly Fried Dragonflies

One tablespoon each of butter, dijon mustard and soy sauce are heated in the pan for a few minutes. Sliced Portobello mushrooms and a pinch of garlic powder are sautéed in a small amount of butter in another pan. After the oil is thoroughly heated, the dragonflies are cooked for 30 seconds on one side for 30 seconds on the other side (Zack Lemann, Audubon Butterfly Garden and Insectarium, New Orleans, Louisiana (Oaklander, 2015).

Figure 5. Chef Zack Lemann's Lightly Fried Dragonflies

Chef Hugo Ortega's Mescal Worm Tacos

After frying in butter, olive oil and white onion, Mezcal worms are lightly sautéed and finally served with fresh parsley and serrano pepper. (Hugo Ortega, Hugo's, Backstreet Cafe and Caracol, Houston, Texas (Oaklander, 2015).

Figure 6. Chef Hugo Ortega's Mescal Worm Tacos

Daniella Martin's Mealworm Slaw

After the mealworms are baked in the oven until golden brown, they are salted and served over the cabbage salad. (Daniella Martin, insect-eating expert (Oaklander, 2015).

Figure 7. Daniella Martin's Mealworm Slaw

Paul Landkamer's Marinated Stink Bugs

Skunk bugs marinated for a day in cajun sauce (a kind of sauce prepared with mayonnaise, cajun seasoning, tomato paste, onion, and garlic powder) are boiled for 5 minutes. Just before draining, they are cooked in cajun sauce, dried until they reach a crispy taste and served (Oaklander, 2015).

Figure 8. Paul Landkamer's Marinated Stink Bugs

Chef Gordon's Deep-Fried Tarantulas

First, tarantulas are frozen, ending their vital functions. After removing the liquid-filled bellies of the frozen tarantulas, their body hair is burned with the help of a blowtorch. The tarantulas, which are ready to be cooked, are dipped in tempura dough, and fried in deep oil to be served (Oaklander, 2015).

Figure 9. Chef Gordon's Deep-Fried Tarantulas

Discussion and Conclusion

Sustainability of food resources is becoming more and more important every day for various reasons. Especially meeting the protein requirement is considered as one of the main problems in the future. Insect nutrition comes to the fore as an alternative food source due to reasons such as the decrease in protein sources due to population growth and the inability to reach sufficient and healthy food.

Factors such as food waste, decreased interest in agriculture and animal husbandry, unconscious nutrition, domestic waste, and migration also cause changes in nutrition patterns. Consumption of seafood is common in Turkish culinary culture, especially in coastal areas. For example, shrimp and grasshoppers are insect species that are similar to each other in terms of their skeletal structure and nutritional content. It is very important for people to be aware of insect consumption. Edible insects have benefits such as less harmful gas emissions, less land requirement, low technology, and low capital investment. Insects, which also offer many advantages as food, are very rich in vitamins, proteins, and minerals.

In this context, it is thought that the use of edible insects as a sustainable food alternative will be a useful solution for possible future problems such as famine,

crises, etc. FAO wants insect farms to be established and insect consumption to be supported to solve the food problem. However, factors such as people's dietary habits, religious beliefs, nutritional culture and not finding insects very safe in terms of hygiene will affect the edibility of insects in different ways. It is also very important to choose the right storage conditions and cooking methods for insects.

Considering the contribution of edible insects to the ecosystem, insect consumption should be planned in a way that does not disturb the ecological balance. Insects can carry biochemical, microbiological, and allergic risks and may be carriers of various diseases. Detailed scientific studies on insects are not available in the current literature. It is important to carry out the necessary scientific studies in the dissemination of insect consumption as an alternative food source.

Compliance with Ethical Standards

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Ethics committee approval is not required.

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