

Review article

The microbiological safety of animal-derived food from organic farms

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Abstract The market for organic food is expanding as consumer interest in organic foods increases. Achieving quality standards requires overcoming challenges common in organic food production systems: the occurrence of bacterial pathogens like *Salmonella*, *Campylobacter*, *Listeria monocytogenes*, *Staphylococcus aureus*, and pathogenic *Escherichia coli*. We expect organic products to meet or surpass the safety and quality of their conventional counterparts. Antimicrobial-resistant bacteria, however, are more commonly found in conventional food products than in organic ones. This review's objective is to discuss recent data on the microbiological safety of animal-derived foods raised on organic farms.

Keywords: Organic food, Organic farming, Food safety, Food-borne pathogens

1.0. Introduction

In the recent past across many regions of the world especially Europe and Africa, the organic food industry has experienced a period of continuous growth [1]. As at the time of writing this article, latest up to 69.8 million hectares of land has been utilized in at least 181 countries by a population of 2.9 million farmers for organic agricultural purposes [2]. These numbers have greatly increased compared with those from the year 1999 when only 11 million hectares of land was used and that by only 200,000 farmers. Another report showed that about 5.2 million sheep, 50 million poultry, 4 million

bovines and 1 million pigs were organically reared in the year 2017. A growing increase of 75.8%, 73.6%, 47.6%, and 103%, respectively, were also reported from 2008 and the years following [3]. The widely held notion that organic products have more health benefits is one of the key factors influencing consumer behavior shifts. Such products according to the consumer, are safe and of higher quality than conventional ones. It is however unfortunate that this is not always the case. The increase in demand for these products and the consequent increase in production often negatively impact the quality and general safety of the organic product. Furthermore, although an or-

ganic farming system is considered to be better for animal welfare since it gives the livestock access to fresh air, it also has the danger of increasing their exposure to diseases from among themselves as well as from the environment. The primary distinctions between conventional and organic animal husbandry results from the latter's adherence to ecological principles; housing, feeding (mostly organic feed), and enabling animal expression of natural behavior (such as nesting) [4], furthermore, the use of antibiotics as a preventative on animals is prohibited in this system of production. These medications can only be used under very specific circumstances such as when the use of homotherapy or phytotherapy proves ineffective in the management of animal diseases [5]. The defined tolerable limits however, have occasionally been exceeded as revealed by food analysis for antibiotic residues [6]. Truth be told, there is bound to be microbial presence in organic livestock production due to the restrictions on the use of antimicrobials in the system, there is also a probability that the products from these animals which eventually reach the markets are also contaminated [7]. Additionally, many intestinal bacteria (like *Salmonella*, *Escherichia coli* and *Campylobacter*.) that can cause serious diseases in humans are asymptomatic in animals because the organisms are a part of the normal intestinal microflora of the animals. The most prominent case of this is the Shiga toxin produced by the organism *E. coli*, which even when present in very low concentration in food, can induce severe disease in people [8]. Thus the potential for bacterial infections from microorganism like *Salmonella*, *Campylobacter*, *Staphylococcus*, and *E. coli* have been recognized as a risk common in organic food farming. Moreover, poultry products among foods of animal origin are frequently associated with very high risk of foodborne diseases, illness, hospitalization, and human mortality [9]. *Salmonella* and *Campylobacter* are the most common pathogens associated with this category. *Salmonella* has been identified to originate primarily from pork and pig products, while Shiga toxin-producing *E. coli* strains are the main significant vector-borne microbes from cow products [10]. In addition to pathogenic *E. coli*, the main hazards to dairy production are *Salmonella*, *Campylobacter*, *Listeria monocytogenes*, and *Staphylococcus aureus* [11]. The existence or non-existence of food microbes in the manufacturing premises or the probability of secondary infectivity of the animal products by the microbes establishes the microbiological safety of the organic product. During the first stages of primary production, such contamination frequently happens. Pathogenic bacteria may be more common, equally prevalent, or less common in organic livestock and food items than in conventionally produced counterparts [12]. This review intends to give a concisely summarize of the microbiological safety of organic food products, based on recent literature.

2.0. Methodology

Scientific articles used for this review were retrieved from the following petroleum journals and databases: "ScienceDirect (<https://www.sciencedirect.com/>), "SPIE Digital Library (<https://www.spiedigitallibrary.org/?SSO=1>), ACS publications (<https://pubs.acs.org/journal/esthag>), SETAC Journals (<https://setac.onlinelibrary.wiley.com/>), PubMed (PubMed (nih.gov), Science Direct (<https://www.sciencedirect.com/>) and Goggle Scholar. The keywords used in the searches were: "Organic food," "organic farming," "food safety," "presence of *Staphylococcus aureus* in organic foods", prevalence of *Salmonella* in organic foods", "prevalence of *Escherichia coli* in organic foods", "effects of *Campylobacter* on organic and conventional farming systems" and "causes of food-borne pathogens", presence of "*Listeria monocytogenes* in food products" , "preventing foodborne

diseases" "testing for bacterial contamination" "economic importance of microbes on foods".

3.0. Food-borne Diseases

Food borne diseases can be caused by several pathogens so that should a contaminated food be consumed, the pathogens release toxins into the body making the individual sick. This section considers the causes of food borne diseases, the organisms that cause them, some tests to identify their presence in food products and ways of preventing their contamination of food.

3.1. Causes of Food Borne Diseases

The three following categories best describes the causes:

- Most infections food borne infections are caused by the microbes' bacteria and viruses which are biological risk factors. They pose the greatest risk to food safety. Food may get contaminated by these microbes because of improper handling or from exposure to the environment (which may cause histamine to develop in some seafood species) [13].
- Some toxins, chemical pollutants and poisons that occur naturally are also examples of risk factors. Other toxins like paralytic shell fish poisoning (PSP) in molluscan shellfish and certain mushrooms can be linked with the food itself. Household chemicals like sulphates may also constitute a risk to people as improper cleaning of food items containing them to get ingested. Allergens present in food may also constitute a risk factor. Wheat, peanuts, milk, crustacean shellfish, eggs, fish, soy and tree nuts make up the more prevalent sources for food allergies [14].
- Glass fragments, metal cans and plastic flakes present in food can constitute the physical risk factors [15].

3.2. Some Common Food Borne Pathogens

3.2.1. Contamination with Shiga Toxin-Producing *Escherichia coli* (Stec)

Food-borne organisms such as pathogenic *E. coli*, particularly *E. coli* O157:H7, can cause epidemics of hemorrhagic colitis, which frequently results in hemolytic uremic syndrome (HUS) among the elderly and even in young people [16]. 5 people according to an investigation were found to have the disease in Poland in 2018, 8161 diagnosis of STEC infection were also found in the EU in general the majority of which were linked to beef and dairy products [17]. 18 people were likewise affected by three *E. coli* O157:H7 outbreaks linked to organic raw meat in the USA. Other 25 persons contracted STEC O157 in Denmark after consuming milk from a small dairy organic farm [18]. Comparing livestock from conventional and organic farms, STEC prevalence was seen to be either equal or lower in the former. The variations in the prevalence of these bacteria according to Haskell et al. [19], had relations with feeding of the animals. Akomoneh et al. [20] also discovered comparable rates of *E. coli* O157:H7 occurrence in cattle from both conventional and organically reared systems. In their investigation, the occurrence of this microbe was 14.8% in organically produced bovine and 14.2% in conventionally produced bovine. According to Gambushe et al. [21] also, 2 out of every 10 organic farming systems have this pathogen present.

3.2.2. Contamination with *Campylobacter*

Campylobacter is among main causative agents of microbial gas-

troenteritis, which typically results in self-limiting diarrhea [22]. There were 246,571 confirmed cases of campylobacteriosis in the EU alone as of 2018 and the two most popular sources of this microbe was unpasteurized cow's milk and broiler meat. According to monitoring information on *Campylobacter* in food, fresh meat from broilers (37.5%) contained the greatest percentage of test-positive units so that organic raw meat was linked to seven *Campylobacter* outbreaks. However, the level of meat contamination was comparable for farms with caged rearing and farms with free-range chickens [23]. Farms with free-range chickens had greater rates of *Campylobacter* prevalence than those with conventional poultry housing (36.7% and 19.7%, respectively). In addition, antimicrobial-free swine breeding had a greater occurrence of *Campylobacter* (77.3%) than did traditional pig farming (27.6%) [24]. In contrast to organic animal breeding, which had a lower prevalence of *Campylobacter*, non-organic animal breeding had a greater percentage of bacteria-positive samples. The incidence of *Campylobacter* was higher on the conventional poultry farms (29.4%) than the free-range poultry farms (25%) [25].

3.2.3. Contamination with *Listeria monocytogenes*

L. monocytogenes is a significant food-borne pathogen that causes the disease listeriosis and is particularly dangerous for young children, pregnant women, the elderly, and people with weakened immune systems [26]. Given the significant mortality rate associated with listeriosis [27], 28 member states, including Poland reported that 2,549 diagnosis were made of listeriosis in the year 2018, of which 15.6% were fatal. As a result, listeriosis is now among the EU's most dangerous food-borne diseases. Milk products and meat from other animal species were substantially less frequently found to have *L. monocytogenes* than ready-to-eat foods comprised of beef [27]. Infections in humans linked to raw meat and organic milk consumed were described in two cases by Ali and Alsayeqh [28]. Similar amounts of *L. monocytogenes*, 26.5% and 26.7%, were found on chicken farms that were conventional and organic [29]. Similar to this, *L. monocytogenes* was found in 60 out of 240 (25%) samples of organic chicken, according to Abou et al. [30]. The 1/2a serogroup made up the majority of the isolates (71.9%), seconded by the 1/2b (21.8%), 4b (4.2%), and 1/2c (2.1%). Of all the recognized *L. monocytogenes*, the 1/2a serogroup is thought to be the one most frequently found in food [31]. On organic and conventional farming systems, other types of *Listeria* species such *L. seeligeri* and *L. innocua* could be traced in 1.3% and 1.8% amounts respectively. In addition, Ricke et al. [29] discovered no appreciable changes in the occurrence of *Listeria* species in eggs or on the farming surroundings of caged versus free-range birds. Out of the 249 samples analyzed, *L. monocytogenes* could be found in 2 of the 7 positive samples for *Listeria*. Additionally, Maćkiw et al. [32] showed that 300 specimens of organic and free-range farms eggs were devoid of *L. monocytogenes*.

3.2.4. Contamination with *Salmonella*

41 diagnoses were made in 2018 in the EU alone with 9,064 other infections in Poland. Bringing the total number of *salmonella* vector food borne epidemic to 1,580. In addition, 30.7% of all food-borne cases of gastrointestinal infections in the EU involving 11,581 humans were traced to *Salmonella*. Some other microorganisms like *S. Enteritidis* and *S. Typhimurium* also caused infections in a part of the population, poultry as well as other raw meat had the highest *Salmonella* samples [33]. However, Popa and Popa [34] reported concerning two outbreaks involving 31 persons that was associated

with consumption of *S. Enteritidis* contaminated organic eggs. Furthermore, a comparatively little number of birds raised organically were examined after slaughter and were found positive for *Salmonella*, this is indicative that animals from the organic farming system are not easily colonized by microorganism [35]. *Salmonella* was discovered more frequently in conventional production (11 out of 208, or 5.3%), compared to organic production (10 out of 387, or 2.6%). One *S. Enteritidis* strain and 18 *S. Typhimurium* strains were also found in an investigation that analyzed samples from farms that breed both caged and free-range poultry [36]. In contrast, a different study found that outdoor farms had a greater rate of *Salmonella*-positive pigs than those who raised them in pig sheds [37]. *Salmonella* was also found on 11% of broiler birds and 20% of organic dairy birds. More so, *Salmonella* was found in similar amounts on conventional and organic dairy farms (5.2% and 4.8%, respectively) according to a study by Wierup et al. [36].

3.2.5. Contamination with *Staphylococcus aureus*

S. aureus and other *Staphylococcus* germs are responsible for food poisoning and human food-borne diseases. Enterotoxins produced by staphylococci during bacterial proliferation is what causes the diseases [38]. In 15 European Countries, 8.4% of 15,598 food samples were in 2018 found to be positive of *Staphylococcus spp.* Furthermore, *staphylococcal* enterotoxins were found in 46 of 3,908 such samples (1.2%; 13). Depending on the farm's production profile, *S. aureus* is frequently found in agricultural settings as well as in meat or eggs. The bacteria are less common on organic crops. 4 from among 300 egg samples from organic and free range poultry farms that underwent microbiological analysis were positive of *S. aureus* [39], whereas 23 out of 220 conventional farm eggs tested positive for the microbe at a 10.5% level. Moreover, when Carrel et al. [40] analyzed meat from different shops, they found that organic samples had a less occurrence of *S. aureus* (16.7%) than samples from conventional production (35.1%). Similar to this, [41] found that raw poultry meat from conventional farms had 27.4% more *S. aureus* than raw poultry meat from farms that did not use antibiotics (13%). The number of samples positive to *S. aureus* was also greater for dairy products that were non-organic (44.8%) than for organic goods (31%). Additional investigations have shown that *S. aureus* is completely absent from livestock maintained in systems that support ecology and wellbeing [42].

3.2.6. Contamination with Antimicrobial Resistant Bacteria

When it comes to public health and the safety of food, antimicrobial-resistant bacteria are of great significant [43]. In contrast to animals raised in an unconstrained system, organic animal production system limits the therapeutic use of antibiotics which appears to reduce the occurrence of antimicrobial resistance in bacterial isolates from organically farmed animals [44]. The majority of research revealed a low prevalence of methicillin-resistant *S. aureus* (MRSA) in poultry, pig, and animals on organic farms. The prevalence of MRSA could be a serious issue and a threat to people's health. MRSA was more pervasive on conventional farms, where it was found in up to 70.1% of herds. It implies that using antibiotics greatly increased the frequency of MRSA in animals raised conventionally. The findings of Rebelo [44] also revealed a greater level of MRSA (15.7%) in meat from non-organic farms compared to meat from farms that did not use antibiotics. *Campylobacter* antimicrobial resistance also happened less frequently in organic cows than in conventional breeding. According to research, 45% of *Campylobacter* isolates from pig farms

utilizing organic practices exhibited antibiotic resistance, as opposed to 80% of isolates from farms not employing organic practices [45]. Additionally, Di Donato et al. [46] found that conventional pig farms had a greater prevalence of *Campylobacter* isolates that were resistant to erythromycin and tetracycline (77% and 83.4%, respectively) than did organic farms (34.5% and 56.2%, respectively). On both organic and conventional farms, however, there were *Enterobacteriaceae* bacteria, particularly *E. coli*, with genes encoding extended-spectrum β -lactamases (ESBL). In 100% of chicken flesh samples from non-organic farms and in 84% of samples from organic farms, detection of ESBL-producing bacteria was made. Trimoxazole, ciprofloxacin, and tobramycin resistance rates were same in both farming systems and were 56%, 14%, and 2%, respectively. Tetracycline-resistant bacteria were, however, more common on conventional (73%) than organic (46%) holdings. Comparable rates of antibiotic resistance *E. coli* were found in both the conventional and organic chicken categories, according to Guarino Amato and Castellini [47]. But when bacteria were extracted from hens from organic farms (43% and 33%, respectively), resistance to antibiotics like ceftazolin and ampicillin was found more frequently than when microbes were obtained from chickens from conventional farms (30% and 24%, respectively). Contrarily, resistance to gentamicin, ampicillin-sulbactam, and trimethoprim-sulfamethoxazole was more common in hens raised conventionally (24%, 18%, and 9%, respectively) than in poultry raised organically (13%, 13%, and 0%, respectively) [47]. Additionally, compared to isolates from conventional farming (97.9%), the incidence of antimicrobial-resistant *Salmonella* was much lower on organic pig farms (54.7%). Tetracycline resistance was highest among the isolates (97.9% vs. 54.7%), then ampicillin resistance (95.7% vs. 39.6%), gentamycin resistance (76.6% vs.

15.1%), and streptomycin resistance (59.6% vs. 54.7%). However, only *Salmonella* obtained from organic farms showed resistance to ceftiofur, cephalothin, and colistin (15.1%, 15.1%, and 1.9% of bacteria, respectively) [48]. In contrast to conventional methods, organic agriculture had a lower prevalence of antibiotic resistance. Animal health is mostly maintained in organic farming through prophylaxis, including management strategies like improved hygiene and reduced livestock densities [49]. The greater restriction on the use of antibiotics may be accountable for the lower prevalence of antimicrobial resistant bacteria in organically farmed animals. Additionally, animals in these farming system showed greater resistance to several bacterial infections colonizing them [50]. Common food borne pathogens are summarized in Table 1.

3.3. Testing For Bacterial Contamination of Food

Bacteria can be found in great variety and abundance in most of the natural world. Although some bacteria are beneficial, others are not. Pathogenic (harmful) and others of potential pathogenic traits can be found in a variety of unanticipated places, including surfaces in homes, the food we consume, and water we drink or use for other things [51]. Unfortunately, the foods and beverages we consume are frequently used as means of spreading disease. Following ingestion, contaminated food travels the gastrointestinal tract to the body and causes typical signs foodborne illness such as nausea, vomiting, diarrhea, and/or stomach pain. The severity of gastrointestinal disorders brought on by bacteria contamination of food can range from minor to highly crippling, even fatal [52]. In the US and even in Europe, food manufacturers and distributors are insisted upon to prove that their products are free of pathogens and worthy to be put up for sale. This is done in order to safeguard the public from disease.

Table 1. SUMMARY OF COMMON FOOD BORNE PATHOGENS

Common food borne pathogens	Causes	Sources
<i>Campylobacter</i>	Campylobacter is the second most typical bacterial cause of diarrhoea.	Raw and undercooked poultry and other meat, raw milk, and untreated water are also sources of campylobacter [7].
<i>Clostridium botulinum</i>	Botulism-causing bacteriaA toxin produced by <i>Clostridium botulinum</i> causes botulism, a potentially fatal condition that can prevent the breathing muscles from pumping air into and out of the lungs.	Foods that are inadequately canned at home are sources of <i>Clostridium botulinum</i> , and young children should not consume honey [4].
<i>E. Coli</i> O157:H6	Bacterium O157:H7 Approximately 73,000 instances of foodborne disease are brought on by the bacteria <i>E. coli</i> O157:H6	Beef, particularly raw or undercooked hamburger, fruit, raw milk, unpasteurized juices, and hard ciders are sources of <i>E. coli</i> O157:H7 [6].
<i>Listeria monocytogenes</i> .	Listeriosis, a dangerous condition that affects infants, pregnant women, and older people with compromised immune systems, is brought on by <i>Listeria monocytogenes</i> .	Unpasteurized dairy items, such as soft cheeses, sliced deli meats, smoked salmon, hot dogs, pate, and deli-prepared salads (such as egg, ham, seafood, and chicken salads) are all sources of <i>Listeria monocytogenes</i> [21].
<i>Norovirus</i>	Norovirus is the most common viral cause of diarrhoea. Norovirus spreads easily from person to person and from infected people to food due to poor hygiene.	Any food contaminated by a person who has the norovirus is a source of the illness [23].
<i>Salmonella</i>	<i>Salmonella</i> is the most frequent bacterial cause of diarrhoea and the leading cause of food-borne fatalities.	<i>Salmonella</i> can be acquired from raw or undercooked eggs, underdone meat and poultry, fresh produce, and unpasteurized dairy products [32].
<i>Staphylococcus</i>	A toxin produced by the bacteria <i>Staphylococcus aureus</i> causes vomiting quickly after consumption.	The prolonged storage of cooked, high-protein foods at room temperature, such as salads, baked goods, and dairy items, are sources of <i>Staphylococcus aureus</i> [35].
<i>Toxoplasma gondii</i>	The parasite <i>Toxoplasma gondii</i> causes toxoplasmosis, a potentially serious condition that can result in abnormalities of the central nervous system, including mental retardation and visual impairment in children. The risk is higher for pregnant women and those with compromised immune systems.	Raw or undercooked pork is one of the <i>Toxoplasma gondii</i> sources [71].
<i>Vulnificus Vibrio</i>	Gastroenteritis, wound infections, and serious bloodstream infections are all brought on by <i>Vibrio vulnificus</i> . Particularly at risk are those with liver disorders.	Seafood, particularly shellfish, that is uncooked or undercooked is a source of <i>Vibrio vulnificus</i> [38].
<i>Shigella</i> .	<i>Shigella</i> causes an estimated 448,000 cases of diarrhea illnesses per year. Poor hygiene causes <i>Shigella</i> to be easily passed from person to person and from infected individuals to food items.	Sources of <i>Shigella</i> : salads, unclean water, and any food handled by someone who is infected with the bacterium [44].

A tried-and-true technique for detecting bacterial contamination in food is through putting the samples on differential and selective culture media, even though “rapid” approaches that use antibody and DNA testing now exist [53]. The tests are easy to use and have a greater intensity of sensitivity and specificity, which outweigh the disadvantage of time consumption common with culture procedures. The sensitivity of all the available tests to assess food safety, including those based on culture, is constrained by the number of bacteria present in a meal sample [54]. By pre-incubating the food sample in a non-selective medium that encourages the growth of any bacteria that might be in the sample, a preparatory procedure known as enrichment culture can be employed to increase the number of bacterial pathogens. There are several medium compositions that enable the separation and identification of harmful bacteria in food. Some tests that confirm the contamination of foods with EHEC (*enterohemorrhagic E. coli*) and other strains of *E. coli*, *S. aureus*, *B. cereus*, *Salmonella*, and *Shigella* are listed in Table 2.

3.4. Preventing Food Borne Diseases

The following steps should be adhered to in order to keep food safe:

3.4.1. Cleanliness

Make sure to get rid of dirt debris and dirt, washing hands with soapy water and ensuring to rinse off with clean water. Sanitize hands and disinfect surfaces as this diminishes bacteria and other pathogens. Employ the use of chemicals like chlorine bleach when necessary. After meal preparation, cutting board and other utensils like dishes should be washed using soapy water, rinsed, then aired or towel dried with clean cloth before the next use. Counter tops too should be cleaned properly with chlorine bleach solutions or alternatively, commercial kitchen sanitizers should be used according to directive by the manufacturers. The sponge used should be sundried so that cross-contamination from the sponge to food products is kept at bay. Even when shopping for groceries, avoid cross-contamination. Separate fish, raw meat and poultry from other groceries to prevent their juice from dripping on other food items. Only use reusable bags for market shopping and never for ready to consume food items. Shopping bags made from clothes should be washed and sundried, and the bags must be totally dried before they can be stored. Contaminating food with other substances when cooking handling and serving should also be avoided. Meals should be served on clean plates.

3.4.2. Cooking

The color of food is not a reliable sign of judging whether food has been properly cooked to the required temperature so that food-borne microbes are eliminated. Another potential risk factor to food safety can arise when time alone is used as criteria for judging that

foods have been cooked properly. It is common to see “x minutes” in recipes. However, the time needed to make sure that a certain dish has reached the appropriate cooking temperature may differ based on the ingredients used or on the thickness of the food. Food thermometer should therefore be employed when appropriate to ensure meals reach their necessary temperature. When it comes to roasting chickens or turkeys, temperature indicators frequently pop up. These appliances show when these meats have reached the safe temperature. Even with the use of these accurate pop-up thermometers, double-checking is still advised. Furthermore, detrimental microbes are slowed from growth by cold temperatures therefore keeping foods cold at 41°F or lower temperature in the refrigerator is advised. An appliance thermometer may also be placed at the back of the fridge to ensure the freezer does not go above 0°F. Refrigeration or freezing of meat, poultry, eggs, and other perishables should be done immediately after purchase. Coolers with ice or gel packs should be used to transport perishable foods. Prepared food and sliced fresh fruits or vegetables, shouldn’t be left at room temperature for longer than two hour and food that has been microwaved or thawed in cold water should be cooked right away. Prior to refreezing, cook the food. Divide big quantities of leftovers into shallow containers to cool more rapidly in the refrigerator.

4.0. Economic Importance of Microbes in Food Products

The expression “Economic Importance” is one which a two-sided meaning; depending on the use, it may have advantages or down-sides. The economic importance of microorganisms in food production and processing is closely correlated with microbiological requirements, standards, or controls. Despite their small size, microorganisms are crucial for evaluating and maintaining the quality of food in manufacturing and food processing industries. Below are some microbes with favorable uses

4.1. *Lactobacillus bulgaricus* and *Strep. theremphiflus*

The production of lactic acid by the microbes *Lactobacillus bulgaricus* and *Strep theremphiflus* during the making of yogurt is one example of how these microbes help to ensure the safety of the product [55]. Lactic acid in addition to enhancing the shelf life of yogurt also prevents the formation of pathogenic organisms, which is crucial for the consumer. Other consumable food items can also be processed using the same method (Figure 1).

4.2. Xanthan Gum

Xanthan gum is a naturally fermented substance made from a superior strain of *Xanthomonas camperstris* grown in pure culture. This microbe decomposes aerobically in a micronutrient-rich media that is mostly composed of carbohydrates. Xanthan Gum has a high viscosity at low concentrations making it an important preservative in

Table 2. SOME TESTS FOR IDENTIFYING BACTERIAL CONTAMINATION IN FOOD

Medium	Selective Agent(s)	Differential Agent(s)	Detection
SMAC (Sorbitol MacConkey Agar)	The majority of Gram positive, non-enteric bacteria are inhibited by bile salts and crystal violet.	pH indicator and sorbitol	<i>E. coli</i> 0157: Gram negative intestinal bacilli will proliferate.Colonies of H7 are colorless and do not ferment sorbitol.
MSA, or Mannitol Salt Agar	Most Gram negative bacteria cannot grow in 7.5% sodium chloride.	pH indicator and mannitol	Bacteria that can withstand salt proliferate; <i>S. aureus</i> ferments mannitol, and its colonies are yellow; <i>B. cereus</i> does not, and its colonies are deep red.
(MAC) MacConkey Agar	The majority of Gram positive, non-enteric bacteria are inhibited by bile salts and crystal violet.	pH gauge and lactose	Gram negative enteric bacilli can thrive, although <i>Salmonella</i> and <i>Shigella</i> spp. do not digest lactose and their colonies are colorless. <i>E. coli</i> produces pink colonies.

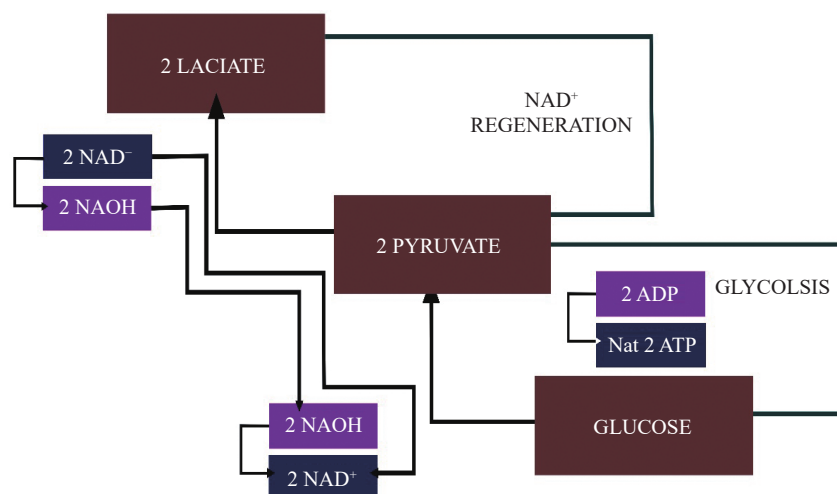


Figure 1. Fermentation process that occurs in compounds

several food industries [56]. It is also alternatively used to stabilize beverages, smooth out cream cheese, prevent ice crystal growth in frozen foods, control ice crystal growth in baked goods, and inhibit syneresis in fruit blends. The liquid enzyme microcatalase is also produced by *Micrococcus lysodeikticus*. This enzyme catalyzes the breakdown of hydrogen peroxide into water and oxygen and thus helps in the curing of raw milk [57].

4.3. Microbe Aided Ripening and Fermentation

Microorganisms are involved in the ripening and fermentation of foods including cheese, fruits, and creams, among others. The typical microorganisms found in cheese include *Brevibacterium linens* and *Penicillium P. camemberti*, *roqueforti*, etc. During surface ripening, *B. linens* creates a brownish-red surface growth on the cheese to convert some of the protein into amino nitrogen, giving it a mild, enticing flavor [58]. To prepare semi-hard Cheeses (Silton, Roquefort, etc.) for consumption, *P. roqueforti* is also used. Similar to this, cream is matured by lactic *leuconostoc mesenteroides* for the manufacture of butter [59].

4.4. Yeast

This is a very useful microorganism in the baking industry. In addition to producing carbon dioxide and ethanol which make the dough to rise, they also make aldehydes and aromatic chemicals. The organoleptic and preservation quality of such products is determined by these microbes [60]. Many yeast species are utilized to produce ethanol, carbonyl compounds, and volatile acids, among other things. Table 3 presents a summary of some organisms and the product they are utilized for

4.5. The Economic Importance of Microbes in the Manufacture of Various Locally Produced Fermented Foods in Africa and Europe

Fermentation is a biological process in which simple sugars are converted to acids, ethanol, and carbon dioxide via metabolic pathways. For example, during the production of yoghurt, lactose gets converted into lactic acid by *Lactobacillus* and *Strep. Thermophilus* [61]. Additionally, for the manufacture of alcoholic beverages (beer, cider, wine, spirit, etc.), yeast (*S. calbergensis* and *S. cerevisiae*) converts glucose to ethanol and carbon dioxide. Microbes have thus been seen to have significant roles in cost reduction [9]. The actions of

these organisms allow for the successful processing of foods including cheese, yogurt, garri and fufu. Below are some specific examples

4.5.1. Garri

Peeling is done on a fresh cassava tuber to get rid of the thin, brownish skin. The inner, whitish portion is then mechanically grated and put in canvas bags to ferment for 18 to 48 hours [62]. Heavy items are placed on the cloth bags to dewater the mash. The mash when desiccated is heated in an iron saucepan to produce garri.

The bacterium *Corynebacterium manihoti* is crucial during the first stage (48 hours) of this fermentation process as it converts the starch to lactic acid [63]. This results in a decrease in pH value and promotes the quick decomposition of linamarin ushering in the second stage. In the second stage, the fungus *Geotrichum candidum* proliferates and creates the favorable aldehydes, ketones. The fermenting mash also contains *Candida* species, *Lactobacillus* species and *Leuconostoc sp* which together create linamarse, the organism that decomposes linamarin and eliminates cyanide from garri [64].

4.5.2. Fufu

To prepare fufu, fresh cassava tubers are peeled, washed and soaked in water. Before soaking, they are cut into smaller chunks and the soaking is done in drums for 3-5 days to allow for fermentation. During this lactic acid fermentation, the pH value decreases and the tubers get softened. The cyanogenic compounds from the cassava are also reduced by this process [65]. Pectinase is produced from the dissolution of the pectin in the cell walls of the *Bacillus* species in the cassava root. Immediately following pectinase activity, the lactic acid bacteria (LAB) produces flavor. Next, the soft tubers are sieved, given time to settle, and then dewatered using a press [66].

Concluding Thoughts

The rapid growth of organic food production which is attributed to consumer demand is a promising trend driven by public notion that organic is both safer and of higher quality. Although scientific evidence that supports the notion that organic food is safer is not inconclusive. Organic farming no doubts promotes improved antimicrobial stewardship in livestock and restricts the use of antibiotics however, its particular impact on food safety remains an area of ongoing study. One significant discovery from the investigations reviewed in this work is the decreasing trend of the multidrug-resis-

Table 3. SOME BACTERIA AND THE FOODS THEY PRODUCED

ORGANISM	PRODUCT IT IS UTILIZED FOR
<i>Aspergillus campestris</i>	The gum Xanthan
<i>cremoris</i>	Gouda cheese and ripe cream muffin
Subspecies of <i>Leuconostoc mesenteroides</i>	Gouda Cheese and butter, ripe
<i>lactic</i> subspecies of <i>Lactococcus</i>	Gouda Cheese with mature cream butter
<i>lactic sub. c. cremoris</i> <i>Lactococcus</i>	sausage
<i>Micrococcus</i> and <i>Pediococcus</i> Sp.	Polish salami or sausage - Summer
<i>S. cerevisiae</i> and <i>Lactobacillus</i> Spp	Produced from processed meat
<i>S. calbergensis</i>	Beer production
<i>Bacillus bedsheets</i>	Brie (East Paris) Cheese
Casein color of penicillin	Brie (East Paris) Cheese
<i>Glaucum, P.</i>	The blue cheese
<i>Candidium P</i>	Cheese Camembert
<i>P. camembert</i> Var Thom	Camembert Cheese
<i>Thermophilus streptococcus</i>	Yoghurt
<i>Lactic streptococci</i>	(Culture cream) Butter
Strain of <i>Cremoris</i>	Butter (culture cream)
<i>diacetilactis streptococcal</i>	Butter cream/yogurt
<i>Ilrovorum Leuconostoc</i>	Cheese/Butter cream
<i>Casein lactobacil</i>	Cheese
<i>lactic acid bacteria</i>	Cheese
<i>Helveticus Lactobacillus</i>	The cheese emmenthal
<i>Lactobacillus bulgricus</i>	Yoghurt
<i>Geographical candidum</i>	Gari
<i>Manihorli Corynebacterium</i>	Gari
<i>Sp. Acetobacter</i>	Vinegar
<i>Oryzae Aspergillus</i>	Soy Cheese
<i>Rasmus Mucor</i>	Norway Cheese
<i>the antibiotic roqueforti</i>	Roquefort Cheese

tant strains in favor of the organic farming system compared to the conventional ones. This finding is heartening as it suggest that the organic farming system may have roles in decreasing the circulation of antimicrobial resistance strains which is important in the context of the expected global increase in antimicrobial consumption. Mitigating the spread and development of antimicrobial resistant microbes is of crucial importance to safeguard the health of the public and to maintain the effectiveness of existing antimicrobial drugs. On the other hand, regarding the presence of microbes in organic food products, different findings from different investigations present conflicting results and this inconsistency makes it difficult to draw definitive conclusions on the impact of organic production on the prevalence of microbial contaminants in the products. Thus adequate research is needed in this area to achieve a comprehensive understanding of the relationship between organic food farming system and microbial contamination by microbes. The organic farming systems in the European Union provide a comprehensive framework for regulation of agricultural products, including aquaculture and yeast, at all stages of the production process. These strict regulations nonetheless, the identification systems in Europe based on the analysis conducted show that *Salmonella* was the predominant pathogen reported in both organic food and feed, seeds being the most affected. *Salmonella* is a major cause of foodborne diseases worldwide and poses a considerable risk to public health. The detection of a single foodborne outbreak linked with *Salmonella* enteritidis in eggs suggests that current safety measures may be effective in controlling and preventing large scale outbreaks. However, continued surveillance and targeted interventions are necessary to further reduce the risk of foodborne diseases. Furthermore, the fact that seeds are the most affected food products also points to specific areas requiring attention and more research. Sanitary control is also vital in addressing the complexities of food safety in organic production. Understanding how organic practices influence the occurrence of microbial contamination, the spread of antibiotic-resistant genes and the emergence of certain

bacteria will guide the development of targeted and effective food strategies. Researchers in their bid to gain a better understanding of the impact of microbial contamination on organic food production must consider such factors as soil health, farm management practices, and regional and climate differences. Comparative investigations on organic farms in diverse geographical locations and conventional farms will provide valuable insights into the complex interactions between microbial ecology and agricultural practices. Conclusively, this study is limited by its primary reliance on scientific literature as a main source of information on reported effects of microbial count on organic farming system. Idyllically, accessing the country or community specific public health databases would provide a more comprehensive data. Nevertheless, this approach would have been limited by language barriers.

Recommendations and Future Perspectives

The future of microbiological safety in organic farms and animal-originated food is promising, with advancements and current research aimed at enhancing food quality and safety. Primary areas of focus should include:

New Detection Methods: The development of fast and accurate detection methods for food borne microorganisms is critical. Techniques including, machine learning and deep learning combined with short-wave infrared hyperspectral imaging should be investigated for their efficiency in identifying contamination in meat [67].

Sustainable Practices: Integrating sustainable practices, such as outdoor access and organic feed for livestock in organic farming, may increase the risk of exposure to zoonotic pathogenic agents from the environment [68]; hence such practices should be avoided.

Natural Antimicrobials: The employment of essential oils with strong antibacterial properties should be considered as a natural strategy for preventing unwanted microbes. Nevertheless, the chemical instability and effect of these on meat proteins limit their usage [69].

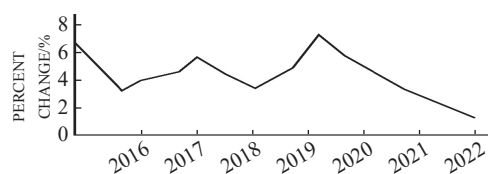


Figure 2. The percentage change in chilled food production globally.

Innovative treatments: Natural strategies and inventive treatments for microbial inactivation and mitigation should be investigated to tackle the challenges of food-borne pathogens [70].

Put together, these advancements will ensure the microbial safety of animal-derived food from organic farms and also protect consumer health. More research and collective efforts between different fields will further help to shape the future of food safety in this sector.

6.0. Conclusion

Consuming foods or drinks that are contaminated with dangerous pathogens, such as bacteria, viruses, or fungi, or their toxins can result in a food borne diseases. Consuming contaminated uncooked, tainted, or raw meat, fish, poultry, produce, canned products, or water can result in foodborne diseases. Depending on the type of pathogen and the intensity of the sickness, recovery times might range from a few days to many months. Healthcare experts may use a combination of DIY cures and over-the-counter or prescription drugs to treat some of these diseases. Frequent hand washing with warm and soapy water, separating raw foods from cooked foods, and storing food appropriately, can help to mitigate the risk of getting a food-borne disease.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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