Positioning Food Provenance and Forensics at the Centre of Sustainable Food Practices

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Abstract

Food provenance and forensics are vital concepts that foster knowledge about where food comes from and carry out investigations to ensure that foodstuffs and food products are safe and quality. This study aims at examining the effect of food provenance and forensics on sustainable food practices. Three main aspects of sustainable food practices, including social impact, environmental impact, and economic impact, were assessed. A survey was created and randomly distributed to 200 people living in Abu Dhabi, out of which 152 responses were successfully completed. Multiple linear regression revealed a significant positive impact of food forensics on society, environment, and economy, while food providence had a significant impact only on society ($p \leq .05$). It was also revealed that food forensics positively and significantly affect nutrition and health, workers' rights and safety, carbon footprint reduction, food loss and waste reduction, and jobs/incomes but had a significant negative effect on corporate profits. Food provenance had a significant positive impact on workers' rights and safety only. It was concluded that food forensics is of greater influence to sustainable food practices than food provenance. Food forensics provides a greater opportunity to foster better nutrition and health, promote workers' rights and safety, reduce carbon footprint, reduce food loss and wastes, and facilitate job opportunities.

Keywords: Food forensics • Food provenance • Sustainability • Society • Environment • Economy

Introduction

United Nations estimates that almost 960 million people are experiencing hunger. This is about 8.9% of the world's population. At the same time, starvation rates had been on the decline from 2000, reducing from 15% in 2000 to 8.9% by 2014 [1]. However, myriad challenges, including the COVID-19 pandemic, have reversed these gains [2]. A study by von Braun et al. highlights that hunger can affect anybody in society, but particular groups of people and those living in certain conditions of life have been found to be more vulnerable than others. The study further identifies persons living in poverty are affected by hunger and lack of adequate food. This is because they hardly have enough income to grow or produce their own food.

Children being dependent on adults in the form of their parents or guardians are particularly vulnerable to hunger. Child hunger is prevalent in both developed and underdeveloped countries. UNICEF estimated that over 3.1 million children die from undernutrition annually. The study points out that over 50.5 million children are wasted, meaning they have very low weight relative to their heights. From the reports in UAE, although the country records comparatively low starvation rates (3.1%) malnutrition remains a significant challenge in the country [3]. World Bank (2021) recorded

undernutrition in UAE at 3.7% in 2019 which was 1% rise from 2015 figures (2.7%). Another report by Global Nutrition Report (2021) shows that UAE is off course to meet its targets with respect to infant, young children, maternal, and adult nutrition. According to the report, 41% of UAE adult women and 27.5% of adult men are obese due to malnourishment [4]. The levels of malnourishment and undernourishment ignited the need to develop a quest towards understanding how food is produced in UAE and safety and quality standards of such foods. Food provenance and forensics provide a robust guide in such conversations.

Agriculture is the primary source of food for the world's population. Largely, agriculture constitutes animal husbandry, crop farming, aquaculture, and forestry. Cereals and oil crops contribute to the largest part of the human diet, providing up to 56% of calories needed by the body. The USA, China, Brazil, and India are the world's largest producers of foods.

World Health Organisation reports that in the current age, the majority of people are currently consuming foods that are very high in energy content, fats, sugars, and salt. The rise in fast food joints has only served to increase these types of foods which are unhealthy in terms of dietary contents. Of great concern is whether current food is not only healthy but also if they safe for human consumption. Unsafe

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food causes ill health to consumers of such foods, and Meybeck and Gitz project that one out of every ten people totaling over 600 million people become sick as a result of eating contaminated food, a pointer to the extent to which the world foods are unsafe and unhealthy for human consumption. Food availability and safety is a matter of urgent concern around the globe, and therefore the inequalities and health concerns that surround food availability and accessibility in the current age demand an urgent redress to foster sustainability throughout food cycles.

Sustainable food systems encompass the social, economic, and environmental sustainability of food systems. A sustainable food system has a wholesome range of actors and their interconnected value adding activities that encompass the production, aggregation, processing, distribution, consumption, and disposal of food products that originate from the main sources of foods [5].

Various approaches can be utilised to promote sustainable long-term food practices. Food provenance and food forensics are some of the approaches that can be utilised towards this end. Tracing the origin of foods consumed and their subsequent movements and handling across the value chains are key to ensuring the safety and healthiness of food when finally, they reach the consumers. Although there is a unanimous agreement among food researchers and enthusiasts that there is a need to foster sustainability in food practices, incongruity exists in how this can be achieved [6]. This study introduces food provenance and food forensics as vital concepts that can greatly stimulate sustainability if well explored and implemented in food practices. Therefore, this study is guided by two specific research questions; to what extent does food provenance influence sustainable food practices? And, to what extent does food forensics influence sustainable food practices?

The study covers major areas in a structure as follows; Section two gives a detailed exploration of the study's theoretical background, detailing the research hypotheses and introducing the conceptual model. The next section details the research methodology adopted, which is then followed by the results. Discussions are detailed in chapter five, and the last chapter expresses the conclusion to the study.

Literature Review

Theoretical review

Sustainability in food systems: With UAE almost wholly reliant on food imports, attainment of sustainable food practices has been challenging as assessment of where and how food is produced and transported and the investigations on the food forensics (quality and safety) are turn out to be painstaking. This has limited the country's ability to develop comprehensive sustainable food systems and plans [7].

Sustainability in the food systems model, developed by the UN's Food and Agriculture Organisation (FAO), provides a robust and extensive approach through which food sustainability can be explored and understood [8]. The model is centred around the main goals that FAO strives to achieve, namely reducing poverty, food security, and nutrition. The model describes and underpins the interrelation between these aims and the three core elements of sustainability in

food systems [9]. Food sustainability must wholly embrace and yield positive social, economic, and environmental effects [10]. Social consequences mean that the food systems must offer specific benefits to the general society; economic outcomes are measured by the profitability that originates from the food systems across the value chain, ensuring the systems provide food security and healthy nutrition across generations [11]. As espoused by Miller, sustainable food systems should leave positive imprints on the environment by ensuring conservation and non-degradation of the domain. The system must provide the natural biodiversity remains unscathed (Figure 1).
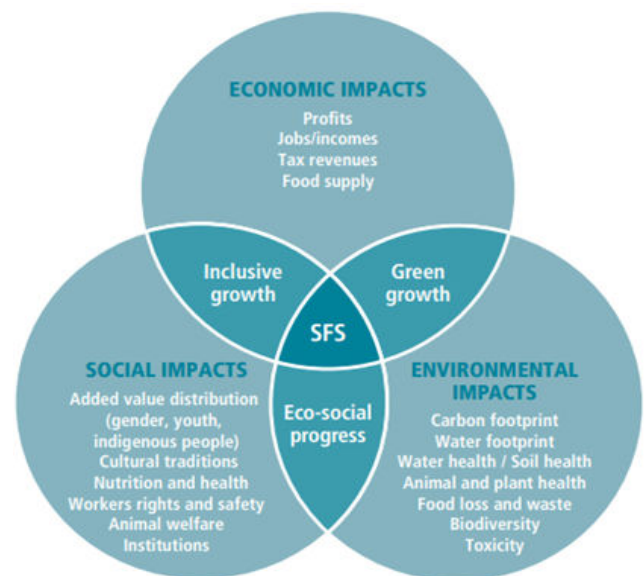

Figure 1. Sustainability in food systems model sourced from FAO, 2014.

Economic impacts: Sustainable food practices offer an opportunity to sector players to minimise costs, thus saving on costs while increasing revenues [12]. A viable economic model can benefit the diverse sector players along the food sustainability value chain [13]. An observation by Oloko is that employees across the value chain should access adequate wages. The government is assured of tax revenues, whereas corporate entities in the sector are assured of payments in terms of profits [14]. As the ultimate beneficiaries of the food products, consumers can gain access to adequate supply to the food systems chain [15].

Social impacts: On the social front, a sustainable food system results in preserving the cultural fabric of a particular society, preserving their native foods and ways of life [16].

It portends that the farmers who produce the foods are cared for and are well rewarded for their work and input in the production and the value chain of ensuring food sustainability [17]. The system should protect workers' rights and guarantee their safety [18]. According to an observation by Oloko, enterprises in the food value chain should ensure they remain authentic by taking firm stands on the values they pursue and passing down education to the consumers who buy food products from them. Education is a key strategy in ensuring that consumers and society at large make better and healthy decisions concerning their food choices and how they prepare and eat them. If well taken care of, social sustainability is a

sure way to guarantee the continued wellbeing of the members of the society and the long life of the community cultures [19].

Broadly, social sustainability guarantees the safety of primary stakeholders, including their health. It also ensures that growers earn a decent income from their agricultural activities, providing food security [20]. Gender parity along the food systems is core to the sustainability and preservation of landscape heritages among the communities.

Environmental impacts: The environment is core to food system sustainability efforts. It influences the success or failure of the main aims of sustainability as it encompasses the resources that are basic to the growth and distribution of foods. Environmental sustainability of the food system relates to no negative impacts on the natural environment or an improved condition of a once degraded environment. The results on the environment consider the natural biodiversity systems, water, and related aquatic resources, including water footprint, social conservation, and carbon footprint.

Wastage of food is a matter of grave concern with the need to devise proper methods to reduce food wastage by half by at least the year 2030 as envisioned by the United Nations.

While there are concerted efforts to reduce the global carbon footprint based on its negative consequences on the global climate, such as global warming, the amount of carbon pollution from global food systems is grossly underestimated. There has been a focus mainly on the methane and nitrous oxide that originate from the production of crop and animal products but ignore carbon dioxide emissions from the overall food supply and value chain.

Structure Conduct Performance (SCP) Paradigm: The structure conduct performance paradigm assists in explaining the theoretical changes in the sustainability of the food system development. Changing trends like population growth, technological forces, and urbanisation constitute the dynamism and complexity of the food system structures. The significance of the food structure involves generating incentives that influence other capacities, which eventually establish their form of conduct. There is an interdependence relationship among the actors in the system, which can impact the incentives and capabilities that one can act.

The integrated conduct of all system actors evaluated in the form of sustainability assists in the food system's general performance. Consumers, farms, and firms, for example, have the capability of influencing the food system as well as influence change. This outcome influences and generates negative or positive feedback influencing the actor's conduct plus the structural system of an evolutionary approach. The structure conduct performance aims to comprehend actors' motivation and influences capabilities while orienting them towards behaviour leading to observed system performance. In addition, it assists in facilitating the growth of the positive performance to generate a self-sustainable process.

Its evaluation concept involves assessing the performance and all environmental, social, and economic standards. According to Neven, It facilitates the identification of potential combinations while assisting in revealing certain exchanges between these three dimensions while ensuring a positive target impact. This often means establishing a variety of expertise from different sectors and other organisations

while developing a clear indication that evaluates every sustainable dimension's effect.

Belik observes that it also assists in developing positive feedback loops, which help generate a self-sustainable process for its improvement. Sustainable food systems aid in engineering growth while advocating for value addition through different components. Some of these essential components involve; salaries for the workers, government tax revenues and their benefits to the consumers, and their effect on the natural environment and its socio-cultural surrounding.

Essential feedback loops involve; investment, multiplier, externalities, and the progress loops driven by the effects of the broader food system and other structures. These feedback loops could be either positive or negative, achieving more sustainability of the food system. Boosting the catalytic support plus the positive feedback loops for both value creation and behaviour change. The system promotes and assists in helping different nations in achieving sustainable development goals. It further leads to wealth generation, thus contributing to responsible utilisation of natural resources and protecting the environment, as Galanakis noted. The structure ensures food security as well as an improved food supply. Eventually, natural habitats and socio-cultural environments assist in making more accessible and desirable products that help in contributing to the security of nutrition.

The structure conduct performance calls for an in-depth comprehension of the structural system, which assists in influencing the stakeholders' actions and how these results affect the overall performance, which affects the structural system over time. The paradigm achieves this objective through analysing the connection within the core systems across the production flow changes, which involve aggregation, production, processing, and distribution. It also evaluates the governance mechanism underlining the power relations among the diverse food system stakeholders, determining the benefits of carrying out the food system activities.

For the structure to enhance performance, the systems should aim to change the behaviour by targeting structural elements affecting both the capabilities and stakeholders' incentives by addressing differences of the organisational levels and the power that ensures balanced relationships. The structural program would assist in developing a joint strategy and vision to improve performance and integrate the solutions that support different stakeholders' partnerships where else improving results. It also helps in facilitating good feedback loops within the system, generating and enhancing the sustainability of the performance improvement process.

Empirical review

Food Provenance as a potential promoter of sustainable food practices: Food provenance means identifying the foods consumed from their origins, across the value chains, until it is finished. Marsden held that to achieve food provenance, the final consumer is required to be educated about the ways of being proactive and taking seriously what they consume, including the health consequences of what their diet contains. According to Nair, it is easier to trace locally grown food. Still, most countries are importers of food products which makes it complicated to accurately trace the origin and handling of such foods before they arrive and are used by the consumers. Food

provenance helps promote sustainable food practices by ensuring that the food value chain adheres to environment conservation, fair economic rights to farmers, especially local farmers, and preservation of societal values and norms. Therefore, it is imperative that all stakeholders keenly get knowledgeable on ways to ensure food provenance, including education to young children on how to trace the food they consume.

Food forensics as a potential promoter of sustainable food practices: Consumers should be able to trace the origin of foods that end up on their tables and how they are handled across the entire food chain. In order to be able to achieve this, von Braun et al. argue that there is a need for adequate and accurate information to inform decisions on what types of food to buy or to consume. Food producers and packagers should provide accurate labelling of the food products detailing the correct contents and quantities of the food products they intend to pass on to the consumers. Food forensics as

a means to this end ensures the social, economic, and environmental pillars of sustainable food systems are all achieved and adhered to.

Food forensics guarantees that the consumers are aware of whether the food they consume originated from and the effects of the processes that led to the preparation conformed to their value systems, beliefs, customs, and traditions. Some food products result in greenhouse gasses and environmental pollution emissions during their preparation, which is all made bare to the consumer once they are exposed to food forensic. The result is that they can demand foods that ensure positive utilisation of the natural environment. Food forensic there directly influences and promotes sustainable food systems.

Hypotheses and conceptual framework

From the literature review, the following hypotheses and conceptual framework were developed (Figure 2).

H_1	Food provenance have positive impacts on the society
H_{1a}	Food provenance positively affects nutrition and health
H_{1b}	Food provenance promotes workers' rights and safety
H_2	Food provenance have positive impacts on the environment
H_{2a}	Food provenance positively affects carbon footprint
H_{2b}	Food provenance reduces food loss and wastes
H_3	Food provenance has a positive impact on the economy
H_{3a}	Food provenance positive affects the profits of food producers
H_{3b}	Food provenance positively affects job opportunities and incomes
H_4	Food forensics have positive impacts on the society
H_{4a}	Food forensics positively affects nutrition and health
H_{4b}	Food forensics promotes workers' rights and safety
H_5	Food forensics have positive impacts on the environment
H_{5a}	Food forensics positively affects carbon footprint
H_{5b}	Food forensics reduces food loss and wastes
H_6	Food forensics has a positive impact on the economy
H_{6a}	Food forensics positive affects the profits of food producers
H_{6b}	Food forensics positively affects job opportunities and incomes

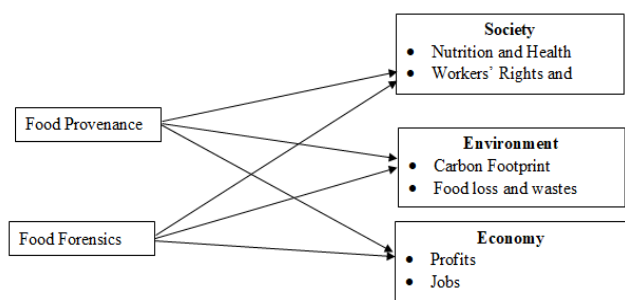**Table 1.** Hypotheses and conceptual framework were developed.

Figure 2. Conceptual framework.

Methodology

Research design: This study adopted a quasi-experimental research design where independent variables were statistically tested against dependent variables to determine cause effect relationships among them. The sustainable food system model was used to determine the dependent variables, which were then used to formulate hypotheses using food provenance and food forensics as the independent variables. The interest at the core of this study was to showcase and statistically prove whether food provenance and food forensics in any way contribute towards sustainable food practices. Adopting a quantitative design, otherwise known as quasi-experimental, provides the best approach to examine relationships among variables.

Data collection procedures: The data collection process was completed through a web based survey targeted to households in Abu Dhabi, UAE. Data was collected from households in which any person within a household, provided they were aged above 19 years of age, were eligible to participate. It was presumed that the targeted participants frequently interacted with food products and were knowledgeable enough to formulate the impacts of their food choices. The participants were recruited randomly. The survey, which was designed and distributed through JISC online survey, was sent to 200 potential respondents, out of which 179 responses were received. An action to remove incomplete responses (*i.e.,* with missing data) reduced the number to 152. The central limit theorem holds that taking sufficiently large random samples from a population with mean µ and standard deviation σ would lead to sample means which are approximately normally distributed. It goes ahead to mention that this assumption would hold true provided given the sample size is sufficiently large (where n ≥ 30). Since the sample size included in this study exceeds 30 by far, it can be deduced that it is sufficiently large and exceeds the requirements of sample sizes.

With regard to the participation of the participants, no incentives were provided to motivate participation, and the participation was fully voluntary. The respondents were assured that the data collected were to be used specifically for the purpose of this study to foster confidentiality. Besides, no personal information that could lead to identification was collected to guarantee anonymity. The participants were briefed and debriefed about the intention of the study, why their participation was vital, and how their data was to be used and handled. Provision of such information and respect to anonymity was imperative in guaranteeing informed and voluntary participation and helped in limiting Common Method Bias (CMB).

Measurement: As initially mentioned, food provenance and food forensics were used as independent variables to model the study. The three primary constructs on which the dependent variables are based (society, environment, and economy) are proven to be resolute pillars of sustainability. In the case of this study, two specific variables under each construct were selected from the sustainability in food systems model developed by Neven for the UN's Food and Agriculture Organisation (FAO). Nonetheless, these specific variables have always been situated as aspects of society, environment, and economy, respectively, as already discussed in the literature review section. The variables were used to directly formulate questions in the survey, making the survey theoretically justifiable. The survey collected data on food provenance, food forensics, and sustainable food practices, where again, the three mentioned constructs were assessed. Food provenance was assessed on three fronts; knowledge about where food is grown, caught, or raised, knowledge about where and how food is produced, and knowledge about how food is transported. Food forensics was assessed on three fronts; interest in expiry dates for food products, interest in ingredients used, keenness on food safety, and keenness on the type of packaging used for the food products. All none-demographic questions were assessed on a 5-point Likert scale (strongly disagree to strongly agree).

Data analysis: It took the participants 10 minutes on average to complete a survey. Upon closure of the data collection window and evaluation, the data file was uploaded to the Statistical Package for the Social Science (SPSSv28) for further analysis. Descriptive

analysis was completed through frequencies where frequency values and percentages were recorded. Inferential analysis to determine significance in the relationship among variables was completed through a linear regression model.

Results

Descriptive analysis

Descriptive analysis completed through frequencies reveals that out of the 152 people who responded to the survey, 79 (53%) were males, 71 (46.7%) were females, and 2 (1.3%) chose not to mention their gender. The age of the respondents averaged at 35 years old. However, as shown in Figure 3, the greatest majority of the respondents (21.1%) were aged 26-30, followed by age brackets 31-35 and 36-40, which were at 17.8% each.
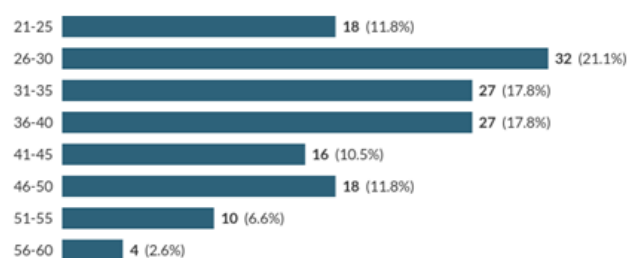

Figure 3. Respondents' characteristics by age.

By the level of education, the sample was sharply skewed towards bachelor's degree (44.1%). Doctorate holders and technical secondary school graduates were the minority at 10.5% and 11.8%, respectively (Figure 4). Around half of the respondents (53.9%) reported that they were married. The majority of them were of Asian descent (32.2%), European descent (15%), or African descent (15%).
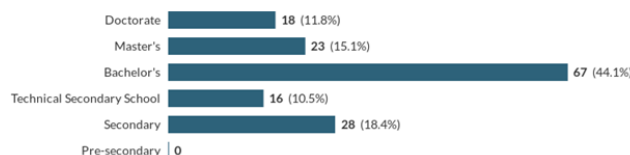

Figure 4. Respondents' characteristics by level of education.

Food provenance was measured using three specific items; concern about where food is grown, caught, or raised, concern about where food is produced, and concern about how food is transported. Descriptive statistics confirm that 70.8% are concerned about where food is grown, caught, or raised, 70.4% showed concern about where food is produced, while only 40.8% agree that they are concerned about how food products use are transported. These figures show that a significant majority of the public population are still incognisant about food providence hence they exhibit less concern about it.

On the same note, food forensics was measured from four fronts; interest in checking expiry dates of food products before use, interest in checking ingredients used in a food product to confirm any form of contamination or adulteration, keenness in buying food products that are produced safely, and keenness in buying food products packaged in environmentally friendly packages. The agreement rate for each of these fronts (calculated by summing cases of 'agree' and 'strongly agree') was 80%, 50%, 74.4%, and 77%, respectively. Again, these

statistics are expectedly low, especially for the case of interest in checking ingredients used in making a food product. Such low statistics ignite the need for sensitisation.

Normality and reliability

At the onset of the data analysis process, it was presumed that the data was normally distributed to meet the standards of the Central Limit Theorem (CLT). To ascertain this presumption, a Q-Q plot test was undertaken. The focus was placed on major variables (food provenance, food forensics, social impacts, environmental impacts, and economic impacts). This was to give a visual certification that indeed the distributions were normal. In a Q-Q plot, normality is affirmed if points form a roughly straight line. A Q-Q plot test returned the results in Figure 5 below. In all the five cases, the plots on expected and observed values were roughly colinear, confirming normality.

Reliability was also tested to determine the degree to which the research method and instrument used in this study produce stable and consistent results. A general reliability test on all the items returned a Cronbach's alpha of 0.872, signifying a good internal consistency which is well above the acceptable minimum (0.70).
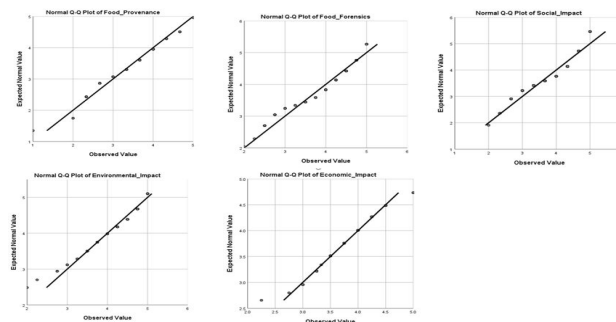

Figure 5. Q-Q Plots.

Regression analysis

In the regression analysis, the two independent variables, food provenance, and food forensics, were tested against nine independent variables; social impact, environmental impact, economic impact, nutrition and health, workers' rights and safety, limited food loss and wastes, limited carbon footprint, profits, jobs, and incomes. The analysis was done at 95% Confidence Interval (CI) and 0.05 significance level. Table 1 below summarises the coefficients attained from the analysis. The test returns a significant relationship if the p-value, otherwise recorded in the table as 'sig.', is equal or less than 0.05 (Table 2).

Coefficients

S. No.	Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)[a]	1.133	0.248		4.561	0
	Food provenance	0.205	0.072	0.242	2.87	0.005
	Food forensics	0.505	0.086	0.494	5.857	0
2	(Constant)[b]	2.464	0.249		9.905	0
	Food provenance	-0.002	0.072	-0.003	-0.031	0.975
	Food forensics	0.428	0.086	0.499	4.957	0
3	(Constant)[c]	3.079	0.181		17.042	0
	Food provenance	0.038	0.052	0.08	0.721	0.472
	Food forensics	0.137	0.063	0.241	2.186	0.03
1[a]	(Constant)[d]	0.878	0.32		2.745	0.007
	Food provenance	0.032	0.092	0.03	0.345	0.731

		B	Std Error	Beta	t	Sig.
	Food forensics	0.816	0.111	0.64	7.362	0
1_b	(Constant)[e]	1.486	0.321		4.635	0
	Food provenance	0.345	0.092	0.359	3.733	0
	Food forensics	0.278	0.111	0.241	2.5	0.014
2_a	(Constant)[f]	2.71	0.323		8.403	0
	Food provenance	-0.01	0.093	-0.011	-0.106	0.916
	Food forensics	0.372	0.112	0.36	3.322	0.001
2_b	(Constant)[g]	2.735	0.361		7.586	0
	Food provenance	0.001	0.104	0.001	0.011	0.992
	Food forensics	0.378	0.125	0.331	3.024	0.003
3_a	(Constant)[h]	4.94	0.469		10.534	0
	Food provenance	0.099	0.135	0.08	0.736	0.463
	Food forensics	-0.604	0.163	-0.403	-3.715	0
3_b	(Constant)[i]	3.054	0.289		10.554	0
	Food provenance	-0.092	0.083	-0.122	-1.1	0.273
	Food forensics	0.328	0.1	0.363	3.274	0.001

a. Dependent variable: Social impact
b. Dependent variable: Environmental impact
c. Dependent variable: Economic impact
d. Dependent variable: Nutrition and health
e. Dependent variable: Workers rights and safety
f. Dependent variable: Limited food loss and waste
g. Dependent variable: Limited carbon footprint
h. Dependent variable: Profits
i. Dependent variable: Jobs and incomes

Table 2. Regression coefficients.

Most of the tested cases turned out to be significant. Regression analysis was first completed on the three major dependent variables, social impact, environmental impact, and economic impact. Results reveal that food forensics have positive significant impact on all the three major variables at p=.000 (ß=.505, t=5.587), p=.000 (ß=.428, t=4.957), and p=.030 (ß=.137, t=2.186) respectively. Although food provenance proved to be of positive significant social impact (p=.005, ß=.205, t=2.87), its impact on the environment and economy remained non-significant (p=.975 and p=.472, respectively). These results provide theoretical support to accept hypotheses H_1, H_4, H_5, and H_6 but to reject hypotheses H_2 and H_3.

'Nutrition and health' and 'workers rights and safety' were theorised to be vital tenets of social impact. It was established that food provenance has positive significant impact on workers' rights and safety (p=.000, ß=.345, t=3.733) but not nutrition and health (p=.731) yet food forensics had positive significant effect on the tenets at p=0.014 (ß=.278, t=2.500) and p=.000 (ß=.816, t=7.362), respectively. These results suggest the acceptance of hypotheses H_{1b}, H_{4a}, and H_{4b} but not H_{1a}. Reduction in food loss and waste and reduction in carbon footprint were also theorised to be vital components of environmental aspect of sustainable food practices. Results uncover that food forensics had positive significant effect on

both of them at p=.001 (ß=.372, t=3.322) and p=.003 (ß=.378, t=3.024), respectively, yet the effect of food providence remained nonsignificant (p=.916 and p=.992, respectively). This leads to acceptance of hypotheses H_{5a} and H_{5b} but rejection of hypotheses H_{2a} and H_{2b}.

Profits and 'jobs and incomes' were theorised to be components of the economic aspect of sustainable food practices. Food provenance and food forensics were tested against them. Again, the results uncover a significant positive effect of food forensics on jobs and incomes (p=.001, ß=.328, t=3.274) and a significant but negative impact on profits (p=.000, ß=.604, t=-3.715). Food forensics proved to be of no significant effect on both profits (p=.463) and 'jobs and incomes (p=0.273). These results suggest acceptance of hypotheses H_{6a} and H_{6b} but not H_{3a} and H_{3b}. The structural model result indicated in Figure 6 below summarises the results. Continuous arrow lines indicate significant effects, while dotted lines imply nonsignificant effects.
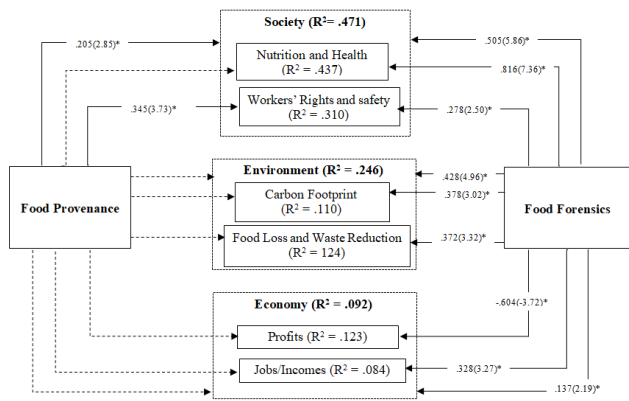
Figure 6. Structural model summarising the regression results (*imply statistically significant at (p ≤ 0.05 while R^2 is the extent to which the independent variables explain changes in the dependent variables).

Discussion

This paper investigated the effect of food provenance and food forensics on sustainable food practices. At the core of the study was the desire to understand the extent to which households and the public at large are privy of and practice food provenance and food forensics and how such practices contribute to sustainable food practices. Although the numbers are significantly large, there is still a large gap of knowledge as those who do not practice food provenance and forensics are also considerably large.

Linear regression model was applied to help relate food provenance and forensics with the three components of sustainable food practices; social impact, environmental impacts, and economic impacts, as well as two tenets of each of three components. The results in this study are in line with research that food forensics is a vital determinant of almost all elements of sustainable food systems. This study finds a significant effect of food forensics on all tested elements of sustainable food practices, including society, environments, and economy and specifically nutrition and health, workers' rights and safety, reduced carbon footprint, food loss, and waste reduction profits, and jobs/incomes. Therefore, this study positions food forensics at the centre of sustainable food practices.

The case is different when it comes to food forensics. Contrary to other studies, this study shows that food provenance significantly and positively affects society but cannot significantly influence the environment and economy. In simpler terms, this study attempts to suggest that being concerned about where food is grown, caught, or raised, how they are produced and how they are transported can promote social sustainability but has nothing to do with environmental and economic sustainability. Among the two tested social factors, food provenance significantly and positively affects workers' rights and safety but interestingly does not affect nutrition and health. Therefore, this study drives off food provenance from the centre of sustainable food practices.

From the results, this study shows that when used collectively, food provenance and food forensics have the potential of improving the society, environment, and economy by 47.1%, 24.6%, and 9.2%, respectively. The results also imply that 43.7% improvement in health

and nutrition, 31% of workers' rights and safety, 12.4% of food loss and waste, 11% of reduction in carbon footprint, 12.3% of corporate profits, and 8.4% of jobs/incomes can be explained by food provenance and forensics collectively. The percentages were attained from R^2 values. This again shows that the two variables are vital concepts in sustainable food practices.

Conclusion

This study contributes to the literature of sustainable food practices by introducing food provenance and food forensics as hypothesised determinants of environmental, social, and economic sustainability with respect to food production, value chains, and consumption. Earlier in this study, an observation was made that although there is a unanimous agreement among food researchers and enthusiasts that there is a need to foster sustainability in food practices, incongruity exists in how this can be achieved. With regard to this statement and the research question, this study finds food forensics as a single factor that can greatly drive sustainable food practices. It finds that food forensics significantly affects the society, environment, and economy, plus their specific determining factors. Although food provenance appeared not to be very promising, it still has significant social impacts. These findings are, to a larger degree, consistent with prior studies and literature on food and sustainability. However, there is a need to examine further why food provenance tends to be less impactful compared to food forensics.

Implications

This study generates multifaceted useful insights and develops knowledge for food providers, producers, and consumers. The insight regarding the significance of food forensics on social, environmental, and economic impacts implies that guaranteeing food quality and safety is vital in promoting all the elements of the sustainability spectrum. This finding reiterates that social, environmental, and economic sustainability are the consequential outcomes of the quality and safety of what people eat. Consistent with this implication, it is fit to recommend the need for the government to take a keen interest in developing laws, policies, and programmes that would promote food safety and quality. The growth of the economy and sustainability of the environment and society depends on it. Food provenance should also not be ignored when it comes to promoting workers' welfare.

To producers, this study implies that embracing food forensics is an opportunity for them to promote workers' rights and safety, reduce their carbon footprint, and promote job opportunities. Workers' welfare can also significantly be promoted by food provenance. However, it might culminate in a problem; reduced profits. This can be explained by the need to commit resources toward food forensics processes. However, these reduced profits might be encountered by increased sales since people generally exhibit a preference towards safe and quality food products.

To consumers, this study finds the need to be keen about the quality and safety of the foods they eat (forensics) as this significantly and positively influences nutrition and health, can help reduce their carbon footprint and can help limit food loss and wastage. Food forensics is a vital concept that consumers should not undervalue. Food provenance has no direct implications for consumers. An

underlying implication to food providers, producers, and consumers is that more emphasis should be placed on food forensics.

Limitations

This study has some limitations that need to be addressed in future research. The first limitation is the sample frame. All the participants recruited in this study were recruited from Abu Dhabi, which is one of the Emirates in UAE, a country situated in the southeast of the Arabian Peninsula neighbouring Oman and Saudi Arabia. Thus, the study specifically concentrates on one place disregarding perceptions from people in other countries. This makes the results more workable in UAE and less generalizable to a global context. Future researchers on a similar topic might need to expand their sample framework across borders. Another limitation in this study develops from the constructs used in the analysis. The dependent variables were developed from the Sustainable Food Systems framework developed by UN's FAO. However, it did not examine all the constructs but ignored some due to limitations by space and time. Future researchers should find it useful to include constructs that were never used in this research.

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