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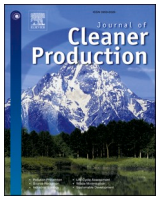

A combined evaluation of energy efficiency, customer satisfaction and food waste in the healthcare sector by comparing cook-hold and cook-chill catering

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ABSTRACT

The healthcare sector greatly impacts the environment through energy, transport, product use, disposal and food service. This requires significant interventions to reduce energy consumption and waste generation and increase customer satisfaction simultaneously. Considering the need to investigate food waste amounts and energy consumption in hospitals, the present research has a triple goal. First, it evaluates energy consumption and efficiency by comparing cook-hold and cook-chill catering. Second, it estimates the customer satisfaction of the served meals and third, it assesses the food waste quantities at lunch and dinner among hospital patients. Specifically, the research combines (a) the evaluation of the energy consumption, based on primary data collected in a cooking center with a production capacity of 1590 meals per production cycle; (b) the investigation of the consumers' behavior among 984 patients located in nine different hospital units in Southern Italy; (c) the measurement of food waste based on questionnaire-survey data. Results highlight the reduction in diesel consumption (– 42%) and in electricity consumption (– 93%), as well as the reduction in food waste (– 85%) when comparing cook-hold with cook-chill catering. This research illustrates a guideline in the field of efficient catering. It helps identify sustainable pathways and interventions toward energy efficiency, customer satisfaction, and food waste minimization for policymakers, healthcare professionals, catering companies or patients.

1. Introduction

Material flow measurement plays a central role in tackling food waste at the final consumption stage, and despite the growing body of research on sustainable development in the healthcare sector (Berniak-Woźny and Rataj, 2023; Xu et al., 2021), the analysis of hospital food waste and catering waste is still under-researched. The healthcare sector affects human health and the environment via energy consumption and pollution (Sherman et al., 2019), accounting for about 5% of global greenhouse gas emissions (NHS, 2020). In the European Union (EU), it is estimated that more than 84 million tons (Mt) of food waste was generated in 2018 from agricultural production to final consumption, which represents approx.—13% of the food produced in the European boundaries (Caldeira et al., 2023). Specifically, 56–80% of the entire amount is generated at the household and food service levels, which means 47 to 67 Mt (Caldeira et al., 2019, 2021). Such material amount corresponds, on average, to over 6% of the entire EU greenhouse gas emissions associated with anthropic activities (European Commission, 2023), estimated at 0.3 Gigatons (Gt) of CO_2eq per year (FAO, 2015; Amicarelli et al., 2021). Further, food waste is responsible for freshwater consumption, with an estimated water footprint of 250 km^3, and for land loss, approximately 1.4 billion hectares of land (Poore and Nemecek, 2018; Our World in Data, 2020).

To minimize food waste, tackle unsustainable consumption patterns and switch from a linear to a circular economy, the United Nations implemented the 17 Sustainable Development Goals (SDGs) in 2015, introducing specific targets for food waste reduction and sustainable consumption behaviors. Considering the growing social inequalities, conflicts, the COVID-19 pandemic and climate change, which undermine food security on the global scale and enhance malnutrition, Goal 2, "Zero Hunger," requires ending hunger, achieving food security and improving nutrition by promoting sustainable agriculture. Moreover, Goal 12, "Responsible Consumption and Production," aims to cut per capita food waste in half at the retail and consumer level and reduce

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food loss along with agricultural production and industrial transformation by 2030. It underlines the nexus between avoidable food waste reduction and safe food waste management, highlighting the need to enhance sustainable valorization pathways for unavoidable food waste (United Nations, 2022).

Like the SDGs, the EU implemented the Farm to Fork Strategy in 2018, which aims to create a fair, healthy and environmentally friendly food system by dropping environmental impacts, protecting biodiversity and achieving food security (Nicastro and Carillo, 2021). Furthermore, the same year, the EU developed the monitoring framework for the circular economy, addressing one specific indicator of food waste and highlighting the need to acquire suitable data and develop relevant methodologies (European Commission, 2018). Hence, the EU has obliged member states to measure and report food waste by introducing the Commission Delegated Decision 1597/2019, which requires member states to measure food waste at least once every four years for each stage of the food supply chain (Official Journal of the European Union, 2019).

The Waste Observatory of the Apulia Region (Regione Puglia, 2023), with references to data on municipal solid waste in Apulia in 2021, has estimated a total amount of waste of over 1.1 Mt. Of such an amount, more than 22% is composed of food waste from kitchens, canteens and catering (255 000 t), which constitutes 98% of the overall organic fraction collected at regional level (260 204 t). Based on these data, it is necessary to improve the performance of canteens and food services regarding food waste minimization and management towards sustainability. Moreover, such interventions would align the canteen and catering sector with the SDGs, the New Circular Economy Action Plan and the European Union Delegated Decision 2019/1597 on food waste measurement.

In light of these premises and considering the definition of "catering service" as outlined by the minimum environmental criteria (Section 3.1.), the present research has a triple goal: (i) First, it evaluates the energy consumption by comparing two different catering services, namely cook-hold and cook-chill, based on primary data collected in a cooking center with a production capacity of 1590 meals per production cycle (i.e., per lunch and dinner); (ii) Second, it investigates the customer's satisfaction among 984 hospital patients; and (iii) Third, it measures food waste at lunch and dinner in nine different hospital units located in Southern Italy, highlighting the main drivers towards food waste reduction. To the best of the authors' knowledge, no studies combine three approaches, namely the energy consumption analysis, the customer's behavior investigation and the food waste measurement in hospital canteens, highlighting the originality of the current research and its utility for either practitioners involved in food service or public authorities.

2. Literature review on food waste in the healthcare sector

The healthcare sector significantly impacts the environment through energy consumption, transport, product use and disposal. Hence, selected studies focus on both solid and organic waste from a holistic perspective (Alharbi et al., 2021). In the field of food waste, Carino et al. (2021) have investigated current sustainable practices in hospital food provision, as well as barriers, enablers and recommendations for implementing sustainable practices in the future through qualitative inquiry and semi-structured interviews. This research highlighted the need to improve communication between units, implement employee training opportunities and enhance infection control restriction, as hospital waste is subject to higher safety and hygiene risks than standard canteens. Further, Paiva et al. (2022) have quantified food waste by comparing a flexible (i.e., choice menu) and an inflexible (i.e., basal diet) ordering system by applying direct measurement. One of the main characteristics of the hospital's food service is the design of the patient menus according to their pathology. However, often, patients do not consume the entire menu. Adopting inflexible ordering systems generates food waste from 11.5 to 35.7%. In contrast, optional menus can increase consumption and decrease food waste but implementing a flexible rather than an inflexible ordering system depends on the hospital's budget and financial aid.

3. Materials and methods

3.1. Research framework, goal and scope

The research considers the definition of catering service included in the minimum environmental criteria introduced by the Ministerial Decree n. 65 of March 10, 2020 (n. 90 of 4 April 2020, art. 4), namely: "the activity that includes the purchase of food and drinks, the preparation of meals with the foodstuffs purchased, the transport and administration of meals, the cleaning of the canteen, the premises of the cooking center and the equipment and crockery used, as well as the management of food surpluses deriving from the preparation and administration of meals" (Gazzetta Ufficiale Repubblica Italiana, 2020).

In the light of the definition, and considering the main variables of "transport of meals," "administration of meals," and "management of food surpluses deriving from the administration of meals," the present research has a triple goal: (i) First, it evaluates the energy consumption by comparing two different catering services, namely cook-hold and cook-chill ones, based on primary data collected in a cooking center with a capacity of 1590 meals per production cycle (i.e., lunch and dinner) per day; (ii) Second, it investigates the customer's satisfaction among 984 hospitals' patients; and (iii) Third, it measures food waste at lunch and dinner in nine different hospital units located in Southern Italy, highlighting the main drivers towards food waste reduction.

3.1.1. Study area and system boundaries

The study area is the Azienda Sanitaria Locale Bari (ASL BA), served by four cooking centers and composed of nine hospital units and 60 hospital wards, including: Altamura (12 wards), Corato (four wards), Di Venere (13 wards), Molfetta (five wards), Monopoli (ten wards), Putignano (five wards), San Paolo (eight wards), Terlizzi (two wards) and Triggiano (one ward). Fig. 1 illustrates the study area referring to the hospital units and the cooking centers.

The energy consumption analysis is based on primary data collected in the cooking center in Bari, which responds to all principles identified by the Regulation of the European Commission n. 853/2004 on the hygiene of foodstuffs (Official Journal of the European Union, 2004) and the Regional Regulation n. 2108/2020, entitled "Guidelines for Hospital Catering" (Bollettino Ufficiale Regiona Puglia, 2021). Further, it includes a specific area addressed to the production of cooking meals for celiac users, inside "a room totally separate from the other rooms, equipped with dedicated tools and facilities" as required by the Delibera di Giunta Regionale Puglia n. 890/2012.

Regarding the supply chain under research, the research applies a gate-to-consumer approach, starting from the meal distribution to the hospital units (after meals cooking) until the final consumption among users. The cook-hold and cook-chill catering has common steps, namely ingredients supplying, storage, preparation and cooking, but different steps follow cooking. Specifically, meals are prepared using the same appliances, technologies and recipes, regardless of the method of service. In addition, employees with the same skills and competencies carry out meal preparation and logistics.

Fig. 2 illustrates the system boundaries of the energy consumption analysis, highlighting the main differences between cook-chill and cook-hold catering. In the field of the cook-chill, five steps are included in the system boundaries, as follows: (i) blast freezing at +10 °C; (ii) storage in cold rooms at +3 °C; (iii) energy consumption to keep the cold temperature during packaging; (iv) transportation with cook-chill trucks at +3 °C; and (v) use of warm trays to boost temperature up to 120 °C for 50 min. As regards the cook-hold, the subsequent phases are considered: (i) warm storage and transportation with non-refrigerated trucks at

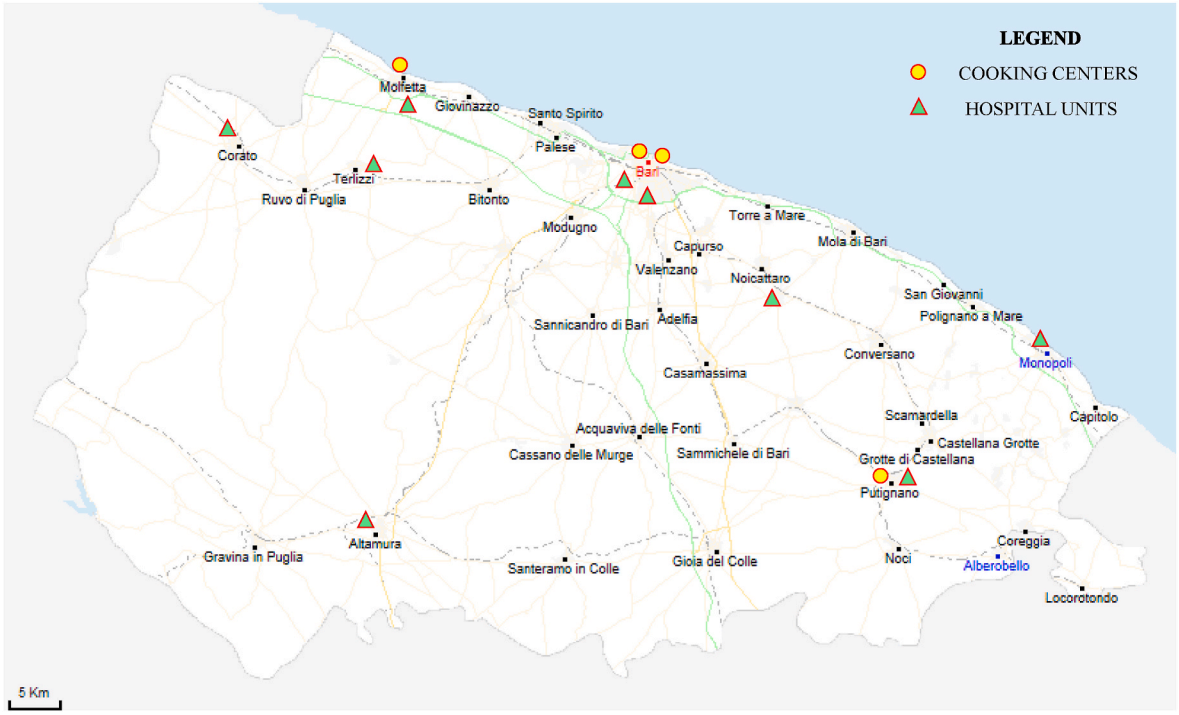

Fig. 1. Study area.
Source: Personal elaboration by the authors.

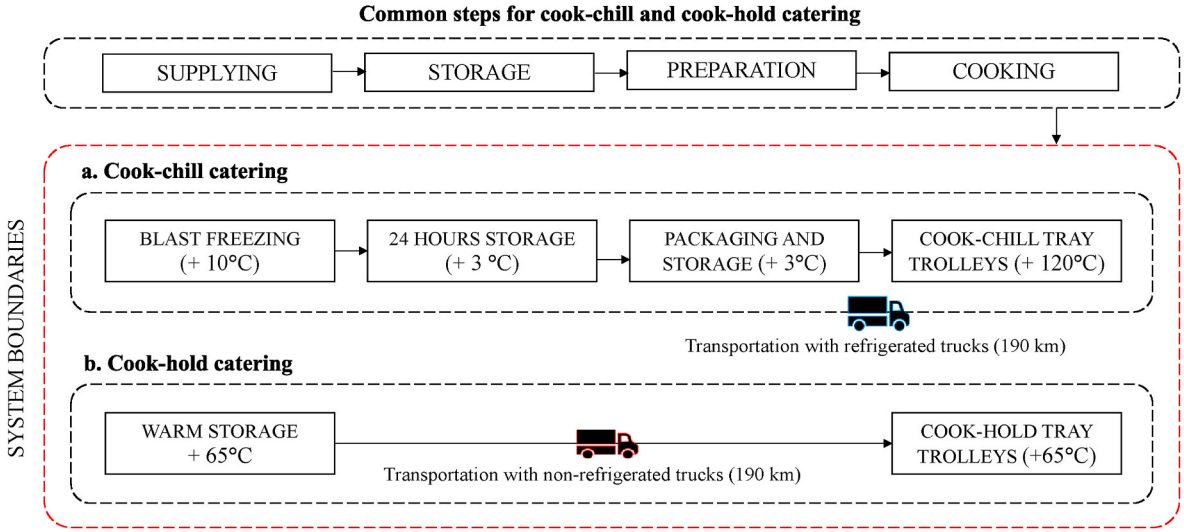

Fig. 2. System boundaries.
Notes: Dashed lines identify the system boundaries of the analysis. Source: Personal elaboration by the authors.

+65 °C and (ii) use of cook-hold warm trays at +65 °C.

3.2. Data collection and analysis

3.2.1. Energy consumption evaluation

Primary data related to the energy consumption evaluation has been collected from one cooking center located in Bari, which has a production capacity of 1590 meals per production cycle (i.e., lunch and dinner) and produces 990 cook-chill meals per day. Primary data related to cook-chill production, as well as data associated with cook-hold production, have been retrieved from the latest energy analysis, developed in line with the International Organization for Standardization (ISO) 50001:2018 on the "Energy Management Systems - Requirements and Guidelines for Use" (ISO, 2018), as well as from the technical specification of the facilities used to transport and serve meals (e.g., insulated vehicle with MASTER tail lift, Renault; single and with double fridge thermal trays with customized trays, Burlodge; porcelain dishes, steel cutlery, unbreakable glass). Moreover, additional information has been acquired from the dashboard provided by the integrated computer system (so-called NOVA), developed in cloud-based technology and delivered in SaaS (Software as a Service) mode. The NOVA system has been realized for managing meal reservations and their reporting, as well as for managing the cooking centers and their traceability. Among the services offered in the field of food tracking and traceability (defined as E-Trace), the software includes data related to the receipt of goods and storage, warehouse withdrawals, production and packaging, as well as

distribution. Specifically, to the distribution of meals, the E-Trace encompasses data related to (i) delivery traceability via electronic shipping documents, (ii) traceability of food trays, (iii) personalized tray traceability to the bed of the patients, (iv) polibox traceability; and (v) traceability of the transported meals. The energetic baseline has been developed according to primary data related to the timeframe July 2021–June 2022, in line with the period of administration of the customer satisfaction analysis (Section 3.2.2.).

Specifically, in the evaluation of the energy consumption, the subsequent variables have been considered: (a) kilometers traveled by trucks; (b) hours of operation of the various machines used in the different service steps, for instance, hours of blast freezing facilities or hours of cold rooms functioning; (c) load factors of trucks, storage rooms and trays; and (d) meals capacity per truck, blast freezing and storage room, and trays.

Table 1 summarizes the variables included in the energy consumption evaluation in the baseline, namely 990 meals in the cook-chill catering and 600 meals in the cook-hold one. Further, the research provides prospective results in the case of an entire production (i.e., 1590 meals) in the cook-hold or the cook-hold catering.

All estimates have also been investigated in terms of tons of oil equivalent (toe) to allow comparison between diesel consumption (expressed in liters) and electricity (expressed in kilowatt-hour, kWh).

3.2.2. Customer satisfaction analysis and questionnaire development

The questionnaire survey addressed to investigate customer satisfaction represents an essential tool to measure and evaluate, on the one side, the organization's efficiency and, on the other side, the needs, and the expectations of the customers (Alaimo et al., 2022), namely the hospital's patients. The questionnaire survey has been developed in line with the documents identified by the Region to determine the customer's approval rating and has been administered weekly from November 22 to November 29, 2021. Anonymous interviews among patients have been carried out by researchers and experts in the field (i.e., hospital dietary staff). The sample has been composed of patients admitted to the ASL BA on selected days per department to avoid addressing patients subject to therapies or hospitalizations without meal delivery, for an amount of 984 respondents.

Regarding meals, respondents have been required to evaluate their satisfaction rating at lunch and dinner, distinguishing between main course, second course and side dish, using a 3-point Likert scale from 1 to 3 (1 = bad, 2 = medium, 3 = good). This value is represented by a smile to make understanding among patients easier. Considering the reasons for disliking, respondents could select the subsequent answers: bad taste, bland, overcooked, little seasoned, al dente, cold, salty, as outlined by previous research (Piciocchi et al., 2022; Donini et al., 2008). Furthermore, results distinguish customer's satisfaction with cook-hold and cook-chill meals.

Questionnaire surveys have been administered using tablets supplied to researchers and expert staff, and data have been cataloged in the NOVA system, a user-friendly management software that provides users with flexible and modular data and catalogs results in a transparent dashboard.

3.2.3. Food waste analysis

In light of the Commission Delegated Decision 1597/2019, the questionnaire administered to explore customer's satisfaction has also investigated food waste quantities by asking each respondent how much food was consumed using the subsequent scale: (a) the entire dish, which means no waste; (b) three-quarter of a dish, which means one-quarter of food waste; (c) half a dish, which means half food waste and (d) no consumption, which means total food waste. The questionnaire graphically identifies such quantities using a circle divided into four equal segments. Table 2 illustrates the menu related to the sampled week, distinguishing per meal (i.e., lunch and dinner) and providing details related to the main course, the second course and the side dish. Meals have been summarized inhomogeneous food categories, as follows: (a) fruit and vegetables; (b) meat and meat products (e.g., ham, meatballs); (c) fish and fish products; (d) dairy products; (e) pasta and baked products (e.g., bread, bread balls); (f) legumes; (g) potatoes; and (h) rice and cereals. It should be considered that each course weighs on average 200 g (equal to 600 g per meal), which is a mean of the weights foreseen by the Regional calls of cooked first course, cooked and cold second course, cooked and cold side dishes.

As to highlight differences in food waste generation according to the catering service, it is possible to distinguish between hospital units with cook-hold meals (i.e., Di Venere, Molfetta, Putignano) and hospital units with cook-chill meals (i.e., Altamura, San Paolo, Monopoli, Corato,

Table 1
Variables included in the energy consumption evaluation.

N.	Cook-chill catering	Hours or km	Unit cons.[1]	Load factor
1.	Blast freezing	7.50 h	6.40 kW h	70%
2.	Storage in cold rooms	24.00 h	7.50 kW h	30%
3.	Energy cons. to keep temperature	4.00 h	7.50 kW h	30%
4.	Trans. with refrigerated trucks	190 km	7 km/L	100%
5.	Use of cook-chill trolleys	0.83 h	8.00 kW h	85%
N.	**Cook-hold catering**	**Hours or km**	**Unit cons.[1]**	**Load factor**
1.	Trans. with non-refrigerated trucks	190 km	12 km/L	100%
2.	Use of cook-hold tray trolleys	0.25 h	6.20 kW h	40%

Notes: Trans. = transportation; cons. = consumption; cap. = capacity; req. = requirement. [1] The "Unit cons." refers to the liters or electricity consumption of each vehicle or each facility. For instance, considering each vehicle contains 180 meals, six vehicles are required to transport meals (i.e., 990/180 = 5.5 = 6 vehicles). The values in the Table consider the km traveled by all vehicles (identified by their license plate) per month, the average quantity of diesel consumed by each vehicle, and the number of meals transported. Source: Personal elaboration by the authors.

Table 2
Menu distinguishing between lunch and dinner per each day.

Day	Meal	Main course	Second course	Side dish
Monday	Lunch	Rice, pasta, vegetables, potatoes	Meat, fish	Legumes, vegetables
	Dinner	Legumes, pasta, broth	Cheese, fish, meat	Vegetable, potatoes
Tuesday	Lunch	Pasta, vegetables, rice	Meat, cheese	Vegetables
	Dinner	Legumes, vegetables, pasta	Vegetables, meat	Legumes, vegetables
Wednesday	Lunch	Pasta, legumes, cheese	Meat, fish, cheese	Vegetables, potatoes
	Dinner	Pasta, legumes, vegetables	Meat, fish	Vegetables
Thursday	Lunch	Pasta, cheese, rice, potatoes	Vegetables, meat, cheese	Vegetables
	Dinner	Pasta, rice, vegetables	Cheese, meat	Vegetables
Friday	Lunch	Pasta, vegetables, fish, rice	Fish, vegetables, cheese	Vegetables
	Dinner	Pasta, vegetables, rice, legumes	Meat, cheese, fish	Vegetables, potatoes
Saturday	Lunch	Pasta, vegetables, legumes	Meat, vegetables	Vegetables, legumes
	Dinner	Pasta, legumes, vegetables	Cheese, fish	Vegetables
Sunday	Lunch	Pasta, rice, vegetables	Meat, cheese	Vegetables
	Dinner	Pasta, vegetables	Meat, fish	Vegetables, legumes

Source: Personal elaboration by the authors.

Terlizzi, Triggiano). Further, results are expressed in weight, considering the number of courses distributed daily with the cook-hold (287 meals, composed of 861 courses) and the cook-chill (697 meals, consisting of 2091 courses) catering.

4. Results and discussion

4.1. Energy consumption results

In light of the energy consumption evaluation, the current energy consumption associated with 990 meals in the cook-chill catering is 0.19 toe, 282.85 kW h of electricity and 162.86 L of diesel. On the side of the cook-hold, catering consumes about 0.08 toe, 12.40 kW h of electricity and 63 L of diesel. Considering the energy consumption per meal, the current cook-chill production consumes 0.28 kW h and 0.16 L of diesel per meal, whereas the cook-hold production consumes 0.05 kW h and 0.15 L per meal. Table 3 illustrates the energy consumption results by comparing the cook-chill (i.e., 990 meals) with the cook-hold (i.e., 600 meals) production in the baseline scenario.

Table 4 illustrates the prospective results in the case of an entire production in the cook-chill and the cook-hold catering, considering the production capacity of the cooking center of 1590 meals.

Cook-hold catering is more efficient than cook-chill one. If all 1590 meals were catered using cook-hold rather than cook-chill, diesel consumption would be reduced by 42% (from 244 to 142 L) and electricity consumption would be reduced by 93% (from 492 to 32 kW h). It also highlights the economies of scale, which can be achieved by maximizing the production of cook-hold meals compared to cook-chill ones in the cooking center. By producing only cook-hold meals per cycle, it is possible to consume 0.09 L of diesel and 0.02 kW per meal, compared to 0.15 L of diesel and 0.31 kW h per meal in the cook-chill production. Regarding toe, the overall energy reduction by switching from cook-chill catering to cook-hold one is 56%.

4.2. Customer satisfaction results

The customer satisfaction questionnaire highlights the main trends related to food consumption and the main drivers for food discarding. The most preferred course is the dry breakfast (100%), followed by the dessert (93.5%) and the second course (89.8%), whereas the least favorite is the first course. Out of the sample, 79.41% of the patients have defined the weekly menu as "good," whereas 16.78% "medium" and 3.81% "bad". As regards the main reasons for discarding, the vast majority of the sample revealed that the meals had a bad smell (22.63%), whereas 19.26% declared that meals were bland and 17.23% that food was overcooked.

Table 5 illustrates the consumption rates distinguishing per day and meal (i.e., lunch and dinner). It provides information related to the different catering, namely the cook-hold (n = 242) and the cook-chill (n = 697), which is a somewhat representative sample size compared to the number of meals distributed weekly. The highest satisfaction rate is associated with the cook-hold catering, being on average 97.88% compared to the 86.21% recorded for the cook-chill meals.

Although determining and interpreting patients' satisfaction is a complex process since many variables should be considered (e.g., hospitalization time, state of health, personal tastes, ongoing therapies), under the theoretical perspective, the analysis of customer's satisfaction with food service represents an essential tool (Piciocchi et al., 2022; Naithani et al., 2008). The education for sustainability among patients and the adoption of cook-hold catering rather than cook-chill one can lead to reducing food waste and its related environmental consequences.

4.3. Food waste analysis

Healthcare food service must provide meals that satisfy the clinical and nutritional needs of patients, as well as guarantee pleasant and satisfying foods, blending nutritional needs and emotional desires. Clinical and nutritional needs are satisfied only if patients consume the entire meal, which is determined in terms of quantity and composition by express predictions of health nature (Piciocchi et al., 2022; Wall and Berry, 2007). Food waste undermines the environment due to the quantity of wasted natural resources (e.g., energy, water), as well as the patients' chance of healing and rehabilitation.

As outlined by the "Guidelines addressed to bodies managing school, workplace, hospital and social canteens and community, to prevent and reduce the waste associated with the administration of food" by the Italian Ministry of Health, the measurement of food waste and plate waste can be conducted by quantitative and semi-quantitative methods, such as the questionnaire administered by the present research, which has been defined as a validated tool (Ministero della Salute, 2018). Table 6 illustrates the weight of food waste distinguishing per day and meals service, considering the number of meals distributed per day in the ASL Bari (i.e., 939 meals, distinguishing between 242 in the cook-hold and 697 in the cook-chill catering, whereas 45 breakfast is out of the analysis). At first glance, cook-hold meals generate a lower

Table 3
Energy consumption evaluation in the baseline.

N.	Cook-chill catering (n = 990 meals)	Daily cons.[1]	Daily cons. (toe)
1.	Blast freezing	33.60 kW h	0.006
2.	Storage in cold rooms	54.00 kW h	0.01
3.	Energy consumption in packaging	9.00 kW h	0.002
4.	Trans. with refrigerated trucks	162.86 L	0.14
5.	Use of cook-chill tray trolleys	186.25 kW h	0.036
	Total (1 + 2 + 3 + 4 + 5)		0.19
N.	**Cook-hold catering (n = 600 meals)**	**Daily cons.[1]**	**Daily cons. (toe)**
1.	Trans. with non-refrigerated trucks	63.33 L	0.08
2.	Use of cook-hold tray trolleys	12.40 kW h	0.004
	Total (1 + 2)		0.08

Notes: Trans. = transportation; cons. = consumption. [1] In the light of the variables included in Table 1, the results of the daily consumption are given for the diesel consumption by applying the subsequent equation: "(190 km/12 km per liter) x 100% × 4 units", or for the blast freezing electricity consumption, as follows: "(7.50 h x 6.40 kW h x 70% × 1 unit)". The meal capacity (i.e., unit) is expressed in terms of meals; for instance, one vehicle transports about 180 meals, whereas one blast freezing facility contains 1000 meals. The units required refer to the number of vehicles or facilities required to supply meals, namely 990 cook-chill meals per production cycle and 600 cook-hold meals per production cycle. Source: Personal elaboration by the authors.

Table 4
Energy consumption evaluation in the prospective scenario.

N.	Cook-chill catering (n = 1590 meals)	Daily cons.	Daily cons. (toe)	Percentage
1.	Blast freezing	67.20 kW h	0.01	4%
2.	Storage in cold rooms	108.00 kW h	0.02	7%
3.	Energy consumption in packaging	18.00 kW h	0.00	1%
4.	Trans. with refrigerated trucks	244.29 L	0.20	69%
5.	Use of cook-chill tray trolleys	299.13 kW h	0.06	19%
	Total (1 + 2 + 3 + 4 + 5)		0.30	100%
N.	**Cook-hold catering (n = 1590 meals)**	**Daily cons.**	**Daily cons. (toe)**	**Percentage**
1.	Trans. with non-refrigerated trucks	142.50 L	0.12	95%
2.	Use of cook-hold tray trolleys	32.86 kW h	0.01	5%
	Total (1 + 2)		0.12	100%

Notes: Trans. = transportation; cons. = consumption. Source: Personal elaboration by the authors.

Table 5
Consumption rates per meal in percentage and frequency (number of observations).

Day	Meal	Cook-hold (n = 242)				Cook-chill (n = 697)						
		DV.	Mo.	Pu.	Mean	A.	SP.	Mon.	Co.	Te.	Tr.	Mean
Monday	L.	100 (7)	96.88 (15)	100 (12)	98.62	97.22 (12)	86.25 (15)	91.36 (15)	92.73 (25)	75.63 (21)	–	87.2
	D.	–	100 (16)	–	100	–	83.47 (16)	63.64 (11)	92.5 (16)	95.39 (19)	–	86.41
Tuesday	L.	–	97.78 (21)	100 (5)	98.21	86.14 (20)	95.31 (20)	74.05 (21)	98.61 (9)	–	–	86.74
	D.	–	97.43 (18)	100 (5)	97.99	–	87.8 (21)	63.64 (22)	51.74 (10)	–	–	70.97
Wednesday	L.	–	–	–	–	–	–	–	–	–	–	–
	D.	–	–	–	–	–	–	–	–	–	–	–
Thursday	L.	96.88 (8)	96.25 (20)	100 (3)	96.78	88.47 (37)	96.09 (16)	85.42 (25)	96.15 (4)	–	–	89.40
	D.	–	100 (21)	100 (2)	100	–	97.01 (17)	85.6 (7)	94.74 (6)	–	–	93.89
Friday	L.	–	93.75 (14)	90.91 (3)	93.25	92.5 (10)	95.49 (18)	100 (3)	92.80 (15)	72.89 (21)	–	87.56
	D.	–	95.52 (16)	90.91 (3)	94.79	–	93.01 (17)	76.75 (8)	73.72 (19)	87.5 (19)	–	83.47
Saturday	L.	99.31 (9)	98.44 (17)	–	98.74	–	95.83 (24)	–	75.00 (8)	–	100 (4)	80.55
	D.	–	100 (25)	–	100	–	90.91 (24)	–	97.73 (11)	–	–	93.05
Sunday	L.	–	–	87.5 (2)	87.50	–	94.26 (16)	–	81.82 (21)	86.27 (18)	–	86.90
	D.	–	–	–	–	–	95.15 (17)	–	93.52 (21)	79.85 (18)	–	89.62
Mean		–	–	–	97.88*	–	–	–	–	–		86.21*

Notes: L = lunch; D = dinner; DV = Di Venere; Mo. = Molfetta; Pu. = Putignano; A. = Altamura; SP. = San Paolo; Mon. = Monopoli; Co. = Corato; Te. = Terlizzi; Tr. = Triggiano. Table 5 identifies in brackets the number of observations per meal. "Mean" is the weighted average of daily cook-hold and cook-chill units. The consumption rate identifies the percentage of meal consumed by each patient and its completion at one corresponds to food waste. The *t*-test has been used to test differences between the means of the cook-hold and the cook-chill units and to understand whether the differences are statistically significant. The null hypothesis (H_0) states that there is no significant difference between the means of the two groups, whereas the alternative hypothesis (H_1) assumes a significant difference. * Considering the significance at p-value $< \alpha = 0.05$, the null hypothesis must be rejected, and it can be assumed that there is a significant difference between means.

Table 6
Food waste per day distinguishing between cook-hold and cook-chill catering.

Day	Meal	Mean CH.	FW/meal/day CH.	Mean CC.	FW/meal/day CC.
Monday	L.	1.38%	0.008 kg	12.80%	0.077 kg
	D.	0	0 kg	13.59%	0.082 kg
Tuesday	L.	1.79	0.011 kg	13.26%	0.080 kg
	D.	2.01%	0.012 kg	29.03%	0.174 kg
Wednesday	L.	–	–	–	–
	D.	–	–	–	–
Thursday	L.	3.22%	0.019 kg	10.6%	0.064 kg
	D.	0	0	6.11%	0.037 kg
Friday	L.	6.75%	0.041 kg	12.44%	0.075 kg
	D.	5.26%	0.032 kg	16.53%	0.099 kg
Saturday	L.	1.26%	0.008 kg	19.45%	0.117 kg
	D.	0	0	6.95%	0.042 kg
Sunday	L.	12.50%	0.075 kg	13.10%	0.079 kg
	D.	–	–	10.38%	0.062 kg
Total		–	0.205 kg	–	0.985 kg

Notes: CH. = cook-hold; CC. = cook-chill; FW = food waste. Food waste data distinguish between daily meals and are aggregated per site per method. "Mean CH." identifies the weighted average of food waste recorded in all sites that use the cook-hold method, whereas "Mean CC." identifies the weighted average of food waste recorded in all sites that use the cook-hold method. "FW/meal/day" illustrates the amount of food waste generated per meal per day. The total amount represents the amount of food waste generated per patient per week.

amount of food waste (2.12%) compared to cook-chill meals (13.79%). The cook-chill method recorded the highest peak at dinner (29.03%). These amounts are lower compared to those identified in Italy by the environmental minimum criteria report (Gazzetta Ufficiale Repubblica Italiana, 2020), which has estimated an average amount of food waste at the hospital level of about 30% of the meals served in terms of weight, which correspond to 27.8% in terms of calories. Regarding food waste per meal, the weekly amount of food waste per patient has been 0.21 kg in the cook-hold method and 0.99 kg in the cook-chill method.

Comparing an average production of 359 160 meals per year, it results that: (a) If all meals are distributed in the cook-hold catering, the amount of food waste would be 4.56 t; (b) If all meals are distributed in the cook-chill catering, the amount of food waste would be 29.71 t. Such a considerable difference highlights the higher efficiency and sustainability, under both environmental and nutritional perspectives, of adopting cook-hold meals compared to cook-chill ones, which would allow a reduction in food waste per year of about 25 149 t (– 85%). From the empirical perspective, the higher amount of cook-chill meal waste depends on the inadequacy of some food categories to be chilled, such as meat and meat products, as well as rice or tomato-based foods. It results that meat-based meals, once cooked, blast chilled, stored in cells for 24 h at +3 °C, and then recovered to 120 °C for 50 min, lose their organoleptic qualities, such as color, shape, smell, or taste Engelund et al. (2007); Gomez et al. (2020). In contrast, meals served soon after being prepared are more likely to preserve the characteristics that patients require, such as the smell and the taste, which makes their satisfaction higher (Section 4.2.) and allows for reducing food waste.

Some additional aspects, although outside the focus of the research, should be remarked, specifically in terms of organizational and managerial aspects. Regarding cook-hold catering, some microbiological risk is associated with hot holding, and failures to hold foods hot have historically contributed to foodborne disease outbreaks in food service establishments worldwide (Bryan, 1990). Moreover, it is not suited and efficient for large-scale food production, as it allows to produce of fewer dishes due to a limited dietary gastronomic proposal and a certain rigidity in the production system (Engelund et al., 2007). In contrast, in cook-chill catering, the microbiological hazards are negligible (Wilkinson et al., 1991), the nutritional values are preserved, and the gastronomic proposal is higher compared to the cook-hold (Engelund et al., 2007), suggesting that cook-chill catering is safer than conventional catering (Wilkinson et al., 1991). Moreover, it allows for a relatively high flexibility in the production process, making it possible to prepare and manage meals with more leeway over time (Greathouse et al., 1989). However, the cook-chill catering is not a cure-all since it cannot produce as many dishes as cook-chill as it permits fewer meal options and requires greater rigidity in the production process (Light and Walker, 1990), due to vitamin losses, for instance (Lassen et al., 2002).

Therefore, it is necessary to identify strategies that manage and balance food safety and quality, production process flexibility, energy efficiency and customer satisfaction (to reduce food waste). In the scope of sustainable development and the ecological transition, the nexus between these variables is a challenge that needs to be faced without delay.

5. Conclusion

The research has proposed a combined evaluation of energy

efficiency, food waste and customer satisfaction in the hospital food service in Bari (Southern Italy) province by comparing cook-hold and cook-chill catering. Specifically, it has developed an energy consumption analysis considering one cooking center with a production capacity of 1590 meals per production cycle day. Moreover, it evaluated the food waste quantities based on 2952 courses distributed daily in nine hospital units and 60 different hospital departments. Last, it investigated consumer behavior among 984 patients to highlight the nexus between customer satisfaction and food waste reduction. Results have highlighted the reduction in diesel consumption (– 42%) and in electricity consumption (– 93%), as well as the reduction in food waste (– 67%) when comparing cook-hold with cook-chill catering. It appears that cook-hold meals generate less food waste (2.54%) compared to cook-chill (11.16%) ones, with cook-hold meals being preferred by most customers. Results have revealed that the satisfaction rate for cook-hold meals is 97.46%, compared to the 88.84% recorded for the cook-chill meals. Under either the managerial or the theoretical perspective, the research proposes a guideline in the field of efficient and sustainable catering. It also helps identify sustainable pathways and interventions toward environmental sustainability and energy efficiency.

Limitations of the current research are related to the evaluation of customer satisfaction in the different hospital units since the analysis does not consider some variables, such as the hospitalization time, the state of health, personal tastes, or the ongoing therapies of the sampled patients. In addition, some uncertainties in the assessment could be due to the quality of ingredients or the experience of the hospital staff in serving meals. For the sake of the research, during the data analysis, the authors assumed that the randomly selected sample was representative of the entire population. Therefore, additional research is required to highlight the nexus between customer satisfaction, environmental protection, and companies' economic needs.

Future research directions intend to carry out an economic and managerial analysis related to cook-hold and cook-chill catering, focusing on possible energy and food savings strategies. Moreover, the researchers intend to investigate alternative sustainable valorization pathways toward food waste minimization and valorization in light of the carbon footprint analysis. Last, future studies intend to detect how to ensure food safety of food distributed with the cook-hold approach and how to increase its flexibility and scale.

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CRediT authorship contribution statement

Christian Bux: Conceptualization, Methodology, Data curation, Software, Resources, Investigation, Writing – original draft, Writing – review & editing. **Giuseppe Zizzo:** Conceptualization, Resources, Investigation, Supervision. **Vera Amicarelli:** Conceptualization, Investigation, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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