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PROGRAMA DE PÓS – GRADUAÇÃO EM CIÊNCIAS APLICADAS À SAÚDE

ERICK CARVALHO CAMPOS

DESENVOLVIMENTO E AVALIAÇÃO DE SISTEMA INTERNET DAS COISAS PARA MONITORAMENTO DE TEMPERATURA DE EQUIPAMENTOS EM UNIDADES DE ALIMENTAÇÃO E NUTRIÇÃO

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Dissertação apresentada ao Programa de Pós-Graduação em Ciências Aplicadas à Saúde, da Universidade Federal de Juiz de Fora, *campus* Governador Valadares, como requisito parcial à obtenção do título de Mestre em Ciências Aplicadas à Saúde. Área de concentração: Biociências.

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RESUMO

A Internet das coisas (*IoT*) tem possibilitado a incorporação de sistemas de informação em toda a cadeia produtiva de alimentos, incluindo em unidades de alimentação e nutrição (UAN). Porém, a disponibilidade e o uso desta tecnologia para o monitoramento de temperatura em UANs, um ponto crítico para a garantia da qualidade das refeições produzidas nestes estabelecimentos, ainda são incipientes. Diante disso, neste estudo se desenvolveu e se avaliou um sistema *IoT* de baixo custo com tecnologia aberta capaz de automatizar o monitoramento da temperatura e da umidade de diferentes equipamentos presentes em UANs. O estudo compreendeu o desenvolvimento da infraestrutura completa contendo dispositivos para a captação dos dados dos equipamentos, rede segura para envio de dados, estrutura de sistemas na nuvem para análise, armazenamento e *feedback* de dados, assim como, a comunicação com os usuários. O sistema foi implementado em uma UAN e avaliado por 130 dias quanto a estabilidade em uso ininterrupto e a satisfação dos usuários. O artefato foi composto, na parte física, pelo microcontrolador *NodeMCU* com *Tasmota 9.5.0.4* embarcado, conectado aos sensores *DS18B20* ou *AHT10* para mensurar a temperatura e a umidade, respectivamente. Os serviços *Node-RED* e *Cloudant* foram mantidos no *IBM Cloud* enquanto os serviços *Mosquitto*, InfluxDB e *Node-RED* foram mantidos na *AWS* para comparação destas opções de nuvem de baixo custo. Os dados foram disponibilizados aos usuários em um painel fixo composto de um monitor de 10" acoplado a um Rasbperry Pi 3B; uma interface web responsiva, um aplicativo para smartphone Android e pelo mensageiro Telegram (apenas para o envio de notificações). Todos os dispositivos funcionaram sem falhas, de forma estável e mostraram-se fisicamente robustos durante os testes. O custo de implementação e de manutenção de todo o conjunto em seis equipamentos distintos da UAN correspondeu a R$ 2.064,44. Nos quatro quesitos avaliados (facilidade de acesso às informações coletadas; satisfação com as notificações de ocorrências; a facilidade de uso do sistema; os benefícios proporcionados devido a implantação do monitoramento), 100% dos usuários se manifestaram satisfeitos (média 34,55%) ou muito satisfeitos (média 65,45%). Conclui-se que o sistema para implementação da tecnologia *IoT* constituiu uma ferramenta de baixo custo capaz de automatizar o monitoramento da temperatura e da umidade em UANs.

Palavras-chaves: internet das coisas, restaurantes, controle de temperatura.

ABSTRACT

The *IoT* technology has enabled adding information systems throughout the food production chain, including food service (FS). However, the availability and use of this technology for temperature monitoring in FS, a critical point for guaranteeing the quality of the meals produced in these establishments, are still incipient. Therefore, the objective of this study was to develop and evaluate a low-cost open technology *IoT* system capable of automating the monitoring of temperature and humidity of different equipment present in FS. The study comprised the development of the complete infrastructure containing electronic devices to gather data from equipment, a secure network for data transmitting, a structure of cloud systems for data analysis, storage and feedback, and communication with users. The system was implemented in an FS and subsequently evaluated for 130 days for stability when in uninterrupted usage and user satisfaction. Its physical part was composed by the NodeMCU microcontroller with *Tasmota 9.5.0.4* embedded, connected to the DS18B20 or AHT10 sensors (temperature and humidity). The *Node-RED* and *Cloudant* online services were maintained on *IBM Cloud*, while *Mosquitto*, *Node-RED*, and InfluxDB were maintained on *AWS*. Data were made available to users through a fixed instrument board consisting of a 10" monitor coupled to a Raspberry Pi 3B; a responsive web interface; an *IoT MQTT Panel* app, and the Telegram messenger (only for sending notifications). The devices have not failed, worked stably, and demonstrated to be physically robust during testing. The cost to implement and maintain the whole system in six different FS's equipment was BRL 2,064.44 (USD 392,96). In the four items evaluated by the users (the ease of access to information; notifications of incidents via smartphones; the benefits that the implementation of monitoring of this equipment brought to the activities developed; the deployed system global quality) 100% provided good feedback, being satisfied (average 34.55%) or very satisfied (average 65.45%). In conclusion, the whole system developed using *IoT* technology provided a low-cost automation tool for temperature and humidity monitoring in FS.

Keywords: internet of things, restaurants, temperature control.

LISTA DE ILUSTRAÇÕES

LISTA DE QUADROS

LISTA DE ABREVIATURAS E SIGLAS

IoT	Internet das coisas ou *Internet of things*
UAN	Unidade de Alimentação e Nutrição
CI/CD	*Continuous integration/Continuous delivery*
P&D	Pesquisa e desenvolvimento

SUMÁRIO

1 INTRODUÇÃO

1.1 UNIDADES DE ALIMENTAÇÃO E NUTRIÇÃO

A cadeia de abastecimento alimentar é uma rede complexa que conecta o sistema de produção agrícola com o consumidor através de uma série de operações como produção/fabricação, embalagem, distribuição e armazenamento (SICHE; SICHE, 2020). Nesta rede, as unidades de alimentação e nutrição (UANs) constituem um dos últimos estágios da cadeia produtiva de alimentos. As UANs consistem em um serviço organizado, que executa uma sequência e sucessão de atos destinados a fornecer refeições balanceadas dentro dos padrões dietéticos e higiênicos, visando, assim, atender às necessidades nutricionais de seus clientes (ABREU; SPINELLI; PINTO, 2009).

As UANs estão presentes de forma bastante difundida na sociedade e englobam inúmeros estabelecimentos que fornecem refeições à população diariamente, estratificados nos macrossegmentos descritos no quadro 1. Estes estabelecimentos integram um relevante segmento econômico global com receita de U$ 2.397 bi ao ano (STATISTA, 2017), no qual tão somente os restaurantes comerciais no Brasil produziram, em 2020, 22,6 milhões de refeições/dia e uma receita de R$ 55,11 bi ao ano (ABERC, 2022).

Quadro 1 - Classificação das Unidades de Alimentação e Nutrição

Macrossegmentos	Tipos de estabelecimentos
Alimentação em empresas	UANs em indústria, comércio e serviço
Alimentação em serviços de saúde ou refeições dietoterápicas	UANs em hospitais e spas, entre outros
Catering de bordo	Refeições servidas em aviões, navios, trens, plataformas marítimas e outros
Alimentação em instituições de educação ou alimentação escolar	UANs em creches, ensino infantil, universidades, entre outros
Alimentação das Forças Armadas	Exército, Marinha, Aeronáutica e Policiais Militares, entre outros
Alimentação comercial	Restaurantes, bares, *fast-foods*, hotéis, buffets, resorts, entre outros

Fonte: Adaptado de Pinheiro Sant'ana (2012)

A receita e o número de refeições produzidas são indicativos da magnitude da inserção das UANs na sociedade brasileira. Essa inserção faz com que estes estabelecimentos atuem como importantes espaços para a promoção da saúde pública (ABRANCHES; OLIVEIRA; JOSÉ, 2021). Devido a isso, independente do porte, do público atendido ou do segmento de atuação, todo serviço provedor de alimentação necessita de um conjunto operacional de recursos e de processos para ser apto a fornecer um produto de qualidade e capaz de prevenir, promover e/ou recuperar a saúde dos clientes.

1.2 INFLUÊNCIA DA TEMPERATURA NA QUALIDADE **HIGIENICOSSANITÁRIA** DE REFEIÇÕES EM UAN

Todo o ramo da alimentação coletiva é regido por um rigoroso e extenso conjunto de legislações, envolvendo a regulamentação de atividades diretas e indiretas do fornecimento de refeições como a produção/fabricação, a importação, a manipulação, o fracionamento, armazenamento, a distribuição, a venda para o consumo final e o transporte de produtos (WENDISCH, 2010). Além disso, este conjunto de legislações estabelece uma série de diretrizes para garantir o tempo e as condições ambientais (temperatura, umidade e presença de contaminantes) necessários para a qualidade de refeições (MAKUN, 2016). Uma vez que o controle dessas condições afeta o processo de decaimento da qualidade (PARK; KWAK; CHANG, 2010) especialmente a temperatura deve ser monitorada durante todo o processo de produção de refeições (BRASIL, 2004) e faz parte do rol de atribuições de nutricionistas em dependendo de sua área de atuação (CFN, [s.d.]).

O controle da temperatura durante o processo de produção de refeições em UAN busca minimizar inadequações ou mudanças inesperadas de temperatura que poderiam levar ao comprometimento da segurança e da qualidade alimentar que, em última análise, poderia resultar em aumento dos níveis de desperdício de alimentos e dos custos de produção, e na perda de confiança do consumidor (BEN-DAYA et al., 2020). Para a manutenção da temperatura dentro dos limites estabelecidos na legislação, requer-se que as UANs estejam munidas de equipamentos capazes de atender as exigências de desempenho e de instrumentos de medição que permitam uma avaliação confiável e eficiente. Além disso, as temperaturas destes equipamentos devem ser aferidas e registradas, o que, de forma geral, é realizado manualmente pelos funcionários e deve ocorrer na forma e na frequência legalmente estabelecidas.

O monitoramento da temperatura impõe aos gestores das UANs um comportamento de vigilância constante para assegurar o cumprimento da legislação e minimizar os riscos de surtos de doenças veiculadas por alimentos (BRASIL, 2020). Porém, devido a carga de trabalho envolvida, o controle da temperatura em UAN pode se tornar um desafio para a gestão da UAN que deve conseguir conciliar essa demanda com todas as outras atribuições da força de trabalho (STICCA; MANDARINI; SILVA, 2019).

Os desafios relacionados ao controle e ao acompanhamento de temperatura na UAN poderiam ser superados por meio da aquisição de equipamentos de automação Internet das Coisas (IoT) munidos de sistemas para monitoramento de temperatura em tempo real, definidos como aqueles capazes de verificar, medir, e relatar a temperatura real a qualquer momento (NDRAHA et al., 2018). Nestes equipamentos, os dados coletados podem ser analisados e transformados em informações úteis que irão oferecer uma visão privilegiada de todos os aspectos da cadeia de produção, permitindo criação de alertas e antecipando situações internas e externas que requeiram ações corretivas (BEN-DAYA et al., 2020).

1.3 A INTERNET DAS COISAS

A Internet vem revolucionando a vida dos seres humanos, ampliando suas aplicações para aproveitar mais serviços e comodidade (KODAN; PARMAR; PATHANIA, 2020a).

Existem diferenças significativas entre a adoção da *IoT* e a informatização de processos em um estabelecimento. Enquanto a *IoT* implica em uma integração entre os dispositivos utilizados para coleta de dados/controle, uma rede e um sistema que permita análise dos dados para mediar a tomada de decisões, a informatização de processos corresponde à utilização da informática para dar agilidade a alguma ação que já era realizada. Um exemplo prático de informatização em UAN e que, portanto, não pode ser confundido com *IoT,* é a tendência contemporânea de utilização de *tablets, smartphones* e aplicativos em procedimentos como o registro de notas ou realização de pedidos.

A *IoT* constitui um dos pilares da indústria 4.0, sendo implementada de diversas formas visando a manutenção preditiva, agricultura de precisão e monitoramento remoto. O quadro 2 abaixo ilustra as áreas de aplicação e seu papel nos diversos ramos da indústria em geral.

Quadro 2 - Aplicações da *IoT* na indústria em geral

Aplicação	**Funcionalidade**
Monitoramento remoto	Captura de dados de dispositivos e monitoramento de performance para aperfeiçoar os sistemas de negócios
Manutenção preditiva	Análise da performance e a condição de equipamentos e máquinas, aplicação de técnicas de análise para realizar previsões de quando a manutenção será necessária
Cadeia de suprimentos conectada	Obtenção de análises em tempo real para aumentar a eficiência e minimizar perdas em toda a cadeia de suprimentos
Gerenciamento de instalações	Gerenciamento de espaços, prédios, fábricas e campos para minimizar desperdício, otimizar a eficiência e aumentar a produtividade
Monitoramento da eficiência geral de equipamentos	Maximização da performance de máquinas, processos e linhas de produção, garantindo operações ideais em relação à capacidade projetada
Agricultura de precisão	Monitoramento, gerenciamento e otimização do uso de terra, água e outros recursos através da coleta de dados que enriqueçam a tomada de decisão

Fonte: Adaptado de Microsoft (2019)

1.4 APLICAÇÃO DA INTERNET DAS COISAS EM UANS

A *IoT* tem possibilitado a conexão de sistemas de informação e o compartilhamento de dados em toda a cadeia produtiva de alimentos, incluindo na gerência da agricultura de precisão, durante a produção, o processamento, o armazenamento, a distribuição e o consumo de alimentos, ou seja, do campo ao prato (DAVIS et al., 2012). Apesar de a indústria usufruir há bastante tempo de recursos de automação digital da produção através de eletrônica e tecnologia da informação e apesar da efervescente produção relacionada à integração de diversos equipamentos e serviços à internet das coisas (CATARINUCCI et al., 2015; IREDALE; ERFANI; LECKIE, 2017; SAHA et al., 2017; SHANG; ZHANG; CHEN, 2012), as aplicações das tecnologias à UANs são incipientes.

As UANs podem se beneficiar da *IoT* de várias maneiras, dependendo do modelo de negócio, da localização, do tamanho e do volume de negócios (FINOIT, 2020). Um sistema de gestão integrada com interfaces para clientes, funcionários, chefs e gerentes, além de terminais de hardware pode coletar informações em tempo real e informar sequências eficientes para execução do serviço (MERCAN et al., 2021).

O desenvolvimento tecnológico das UANs não possui registros significativos na literatura nacional, o que é uma situação atípica. Apesar de ser um setor produtivo que sofre pressões elevadas por desempenho, há uma escassez de produção acadêmica referente a novas tecnologias para este campo. Os resultados obtidos em buscas nos repositórios de publicações científicas indicam majoritariamente menções vagas sobre a importância da inovação para o ramo, mas sem apresentar aspectos aprofundados das tecnologias ou dos desafios para implantá-las.

Por exemplo, dispositivos com IoT abarcada foram construídos para uso em UANs visando a detecção de gás, detecção de chama e temperatura; e aferir a massa de botijões denominado *SmartGás* (MEDEIROS; SANTOS, 2017).

A disponibilidade de equipamentos no mercado que abarcam *IoT* para o monitoramento automatizado de temperatura é incipiente e o custo para aquisição, muitas vezes, pode estar além da capacidade financeira de muitas UANs, especialmente na conjuntura atual (ABRASEL, 2021). Devido a isso, o uso de equipamentos para o monitoramento automatizado de temperatura ainda é limitado a poucas UANs existentes, tornando-se fundamental que elas se adaptem ao momento tecnológico atual. Visando superar essa lacuna, por exemplo, a Taco John 's realizou uma parceria com a empresa SmartSense para implementar o monitoramento automatizado da temperatura dos alimentos usando sensores sem fio (TASMOTA, [s.d.]). Apesar da possibilidade de contratação de serviços de empresas de *IoT*, ainda sim são escassas soluções de baixo custo que possam ser instaladas em equipamentos térmicos disponíveis nas UANs existentes.

1.5 POPULARIZAÇÃO DAS PLACAS DE DESENVOLVIMENTO E SEU IMPACTO NAS NOVAS TECNOLOGIAS

A tecnologia *IoT* possui diversas arquiteturas estruturadas em modelos distintos de camadas (DATTA; BONNET; NIKAEIN, 2014), como a de cinco camadas, composta por: i) camada de dispositivo, ii) camada de rede, iii) camada de suporte de serviço, iv) camada de aplicação, v) e gerenciamento e segurança (KUMAR; MALLICK, 2018).

A camada do dispositivo inclui todos os dispositivos implementados no ambiente e *gateways* de comunicação, o que representa os sensores (por exemplo, temperatura, luz, movimento e localização, etc.), dispositivos que transmitem e recebem informações pela rede de comunicação diretamente ou através de *gateways* (por exemplo, receptores e transmissores), dispositivos de fornecimento de energia (por exemplo, baterias, painéis solares), dispositivos que são capazes de gerenciar funcionalidades e *gateways*. A camada de dispositivo também inclui todas as tecnologias de comunicação relevantes, com e sem fio, comos padrões *CAN, WiFi, Bluetooth, Zigbee,* etc (DATTA; SHARMA, 2017).

A camada de rede fornece os recursos essenciais de dados de dispositivo e a conversão de protocolo relacionado para protocolos de camada de rede. Inclui funcionalidade para a rede (ou seja, conectividade, mobilidade, autenticação, autorização e contabilidade) e camadas de transporte no modelo de referência de protocolo de interconexão de sistemas abertos (OSI) (LLORET et al., 2016). A camada de suporte de serviço representa serviços que permitem aplicativos e serviços de *IoT*. Contém funcionalidades como o processamento e o armazenamento de dados, bem como funcionalidades especializadas, por aplicação e por serviço, uma vez que os serviços emergentes têm requisitos diferentes. A camada de aplicação inclui aplicações e serviços de *IoT*. Finalmente, gerenciamento e segurança referem-se ao gerenciamento e segurança típicos de configuração, topologia, recursos, desempenho, falha e conta (LLORET et al., 2016).

Os circuitos de controle estão presentes na indústria desde a década 70 onde já era possível encontrar microprocessadores de 8-bits como *Intel 8080* e *Zilog Z80*. Estes microprocessadores concentravam centenas de circuitos num invólucro diminuto, de baixo custo e já viabilizavam a implementação de softwares em diversos equipamentos e que, também, poderiam ser atualizados (TREVENNOR, 2012).

Apesar de representar um avanço significativo para a época, as barreiras da acessibilidade à tecnologia ainda eram muito fortes, mesmo para a indústria. Estes microprocessadores dependiam de um conjunto significativo de outros chips para troca de informações *I/O* (derivado do inglês *Input/Output*), dentre outras operações (operações de tempo real, decodificação de endereços, etc.) (TREVENNOR, 2012). Isso fez com que mesmo as atividades de aprendizado e prototipagem demandassem uma infraestrutura maior do que simplesmente o microprocessador que era o objeto principal, o que significava tanto uma barreira no sentido de custos quanto de conhecimento, pois se fazia necessário saber utilizar todos os elementos do conjunto.

Nos anos de 1990, os circuitos foram reduzidos ainda mais e dotados de novas funcionalidades em um mesmo invólucro (TREVENNOR, 2012). Para diferenciar os novos *chips* contendo simultaneamente o processador, a memória *RAM* e *ROM* e circuitos periféricos muito mais poderosos do que a geração anterior, passou-se a empregar o termo microcontrolador para se referenciar a essa nova linhagem, como o *H8-538F* da *Hitachi* (SHMJ, [s.d.]; TREVENNOR, 2012).

Apesar do avanço significativo nos anos 90, que contribuiu para a computação pessoal atingir 1.000.000.000 (um bilhão) de unidades vendidas no início dos anos 2000 (SOH, 2009), a tecnologia continuou restrita a ambientes industriais porque para o público em geral, a facilidade de uso era mais importante que o desempenho e essa barreira ainda não estava vencida.

Em 2005, quando Massimo Benzi, David Cuartielles e Hernando Barragan criaram o *Arduino* no *Interaction Design Institute Ivrea* na Itália teve início a popularização dos microcontroladores para o público leigo (HUGHES, 2016) que expandiu o acesso à ferramenta.

A partir deste momento, as placas de desenvolvimento da *Arduino* passaram a ser incorporadas desde bancadas de *hobbyistas* a grades escolares (TORRONE, 2011) estimulando inúmeros *shields* e placas estimulando inúmeros *shields* e placas de desenvolvimento novas intercompatíveis com o novo padrão de acessibilidade que surgia, criando um ecossistema de microcontroladores poderosos e acessíveis como pode ser visto no quadro 3.

Quadro 3 - Comparativo entre as principais placas de desenvolvimento compatíveis com a plataforma Arduino. NodeMCU V3 e NodeMCU ESP32 são produzidos pela ESPRESSIF

	NodeMCU V3	**NodeMCU ESP32**	**Arduino NANO 3**	**Arduino UNO R3**	**Arduino UNO WIFI R2**	**Arduino MEGA R3**
Microcontrolador	ESP8266	ESP32	ATmega328p	ATmega328p	ATmega4809	ATmega2560
Tensão de operação	3,3 V	3,3 V	5 V	5 V	5 V	5 V
Fonte de energia	7 V - 12 V	2,3 V - 3,6 V	7 V - 12 V	7 V - 12 V	7 V - 12 V	7 V - 12 V
Consumo médio durante operação	15 µA - 400 mA	20 mA - 240 mA	19 mA - 180 mA	45 mA - 80 mA	50 mA - 150 mA	50 mA - 200 mA
Consumo médio durante Deep Sleep	0,5 µA	5 µA	23 µA	35 mA	35 mA	500 µA
Pinos de E/S digitais	16	36.	14	14	14	54
Pinos de E/S digitais com PWM	16	36.	6	6	5	15
Pinos de entrada analógica	1	2	8	6	6	16
Total de pinos SPI / I2C / I2S /	1/2/2/2	2/4/2/2	1/1/1/1	1/1/1/1	1/1/1/1	1/1/1/4

UART						
Corrente DC por pino de E/S	12 mA	20 mA	40 mA	20 mA	20 mA	40 mA
Memória flash	4 MB	4 MB	32 KB	32 KB	48 KB	256 KB
SRAM	64 KB	520 KB	2 KB	2 KB	6 KB	8 KB
EEPROM	512 bytes	-	1024 bytes	1024 bytes	256 bytes	4096 bytes
Clock	80 MHz	80 MHz / 160 MHz	16 MHz	16 MHz	16 MHz	16 MHz
Comprimento	58 mm	52 mm	45 mm	69 mm	69 mm	102 mm
Largura	31 mm	31 mm	18 mm	53 mm	53 mm	53 mm
Possui WI-FI	sim	sim	não	não	sim	não
Possui Bluetooth	não	sim	não	não	não	não
Total de Sensor de toque	não	10	não	não	não	não
Interface Ethernet	não	sim	não	não	não	não
Sensor de temperatura embutido	não	sim	não	não	não	não
Sensor de efeito Hall embutido	não	sim	não	não	não	não
Alimentação pino P4	não	não	não	sim	sim	sim
Conexão USB	sim	sim	sim	sim	sim	sim
Preço médio	R$ 39,00	R$ 66,00	R$ 33,00	R$ 33,00	R$ 67,35	R$ 57,75

Fonte: Adaptado de Diyiot (2019)

A recapitulação de todo o ciclo que permitiu a expansão do acesso a microcontroladores é relevante porque explicita uma evolução tecnológica que torna cada vez mais viável que novos projetos integradores surjam sem que uma gigantesca infraestrutura de *P&D* se faça necessária como ocorria em épocas anteriores.

2 DESENVOLVIMENTO

2.1 ARTIGO CIENTÍFICO

DEVELOPMENT AND IN-FIELD TESTING OF A FULL-FEATURED IOT SYSTEM FOR TEMPERATURE MONITORING IN FOOD SERVICE

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ABSTRACT

The IoT technology has enabled adding information systems throughout the food production chain, including food service (FS). However, the availability and use of this technology for temperature monitoring in FS, a critical point for guaranteeing the quality of the meals produced in these establishments, are still incipient. Therefore, the objective of this study was to develop and evaluate a low-cost open technology IoT system capable of automating the monitoring of temperature and humidity of different equipment present in FS. The study comprised the development of the complete infrastructure containing electronic devices to gather data from equipment, a secure network for data transmission, a structure of cloud systems for data analysis, storage and feedback, as well as communication with users. The system was implemented in a food service and subsequently evaluated for 130 days for stability during uninterrupted usage, all the while gathering information about user satisfaction. Its physical component was composed by the NodeMCU microcontroller embedded with a Tasmota 9.5.0.4, connected to the DS18B20 or AHT10 sensors (temperature and humidity). The Node-RED and Cloudant online services were maintained on IBM Cloud, while Mosquitto, Node-RED, and InfluxDB were maintained on AWS. Data were made available to users through a fixed panel consisting of a 10" monitor coupled to a Raspberry Pi 3B; a responsive web interface; an IoT MQTT Panel app, and the Telegram messenger (only for sending notifications). The devices have not failed, worked stably, and were shown to be physically robust during testing. The cost to implement and maintain the whole system in six different FS equipment was BRL 2,064.44 (USD 392,96). In the four items evaluated by the users (the ease of access to information; notifications of incidents via smartphones; the benefits that the implementation of monitoring of this equipment brought to the activities developed; the deployed system global quality) 100% provided positive feedback, being either satisfied (average 34.55%) or very satisfied (average 65.45%). In conclusion, the whole system developed using IoT technology provided a low-cost automation tool for temperature and humidity monitoring in FS.

Keywords: internet of things, restaurants, temperature control.

HIGHLIGHTS

- A fully open-source low-cost IoT system was designed and field-tested for the food service business.
- The system can measure temperature from -55ºC to 125ºC in intervals of 60 seconds, store data, display the results in graphical form by a fixed instrument board, web dashboard, and Android app.
- Low-cost parts used (NodeMCU microcontroller and DS18B20/AHT10 sensors) survived without any failure for 130 days of the field test.
- Open-source software used (Node-RED, InfluxDB, Mosquitto) ran in a low-cost t2.micro AWS instance

2.1.1 Introduction

In recent years, the internet has been revolutionizing the lives of human beings, expanding its applications to take advantage of more services and provide convenience (KODAN; PARMAR; PATHANIA, 2020b). In this context, the Internet of Things (IoT) is established as a combination of massive data processing, connectivity, and ease of use with the potential to be applied in several areas. *IoT* is defined as the cluster of two terms: the first one is the internet, referred to as a network of networks, which connects many users with standard Internet protocols. The second term is Thing, which refers to devices or objects that transform into smart objects (KUMAR GOYAL et al., 2018). This concept includes a technical transformation of manufacturing, extending the digital connectivity products, processes, and factories. The essence of IoT is an increasingly powerful and low-cost application of computing and network information technologies in enterprises (DAVIS et al., 2012).

The IoT has made it possible to connect information systems and share data throughout the food production chain, starting at the management of precision agriculture, continuing through production, processing, storage, distribution, and consumption of food – in other words, its applications extend from farm to plate (DAVIS et al., 2012). The food service (FS) constitutes one of the last stages of the food production chain and surely can benefit from the IoT. The FS are spaces for public health promotion (ABRANCHES; OLIVEIRA; JOSÉ, 2021) through the nutritional provision of communities, including restaurants, catering, hospitals, military forces, among others.

FS constitutes a relevant global market with annual revenue of USD 2,397 billion (STATISTA, 2017). Brazilian restaurants alone served, by 2015, an amount of 18.77 million meals by day, accomplishing BRL 40.08 (USD 7.69) billion revenue, increasing to 22.6 million meals/day and a revenue of BRL 55.11 (USD 10.57) billion per year by 2020 (ABERC, 2022).

FS can benefit from IoT in several ways, depending on the business model, location, and size (FINOIT, 2020). An integrated management system providing graphical user interfaces for customers, employees, chefs, and managers, in addition to hardware terminals, can gather and share information in real-time, thus constructing efficient service sequences (MERCAN et al., 2021). Studies have demonstrated the application of information systems technology in both restaurants and institutional food services for waste management (HU et al., 2018), for menu selection and remote orders by customers (BREWER; SEBBY, 2021; GUPTA, 2019), for parking space location (SAEED et al., 2017), meal delivery status follow-up, self-monitoring of beverage inventory, and restaurant supplies management (LEE, 2019).

In FS, IoT can mitigate essential concerns, especially related to the sanitary adequation of food, which is determined by time and environmental conditions, like temperature, humidity, and the presence of contaminants (MAKUN, 2016). Considering how control of these conditions affects the quality decay curve (PARK; KWAK; CHANG, 2010), temperature, especially, must be monitored throughout the meal production process (BRASIL, 2004). Through this monitoring, we seek to minimize inadequacies or unexpected temperature changes which could lead to compromised food safety and quality which, ultimately, could result in increased levels of food waste and production costs, as well as the loss of consumer confidence (BEN-DAYA et al., 2020).

The measurement and recording of temperature in FS, when it occurs, are mainly performed manually and is supposed to happen in the form and frequency that are legally established. However, executing these procedures is a challenge for the FS's management due to the high observed workload in those establishments (STICCA; MANDARINI; SILVA, 2019). These challenges related to temperature control and monitoring in FS could be overcome by implementing IoT automation tools for real-time temperature monitoring, capable of verifying, measuring, and reporting the actual temperature at any given moment with virtually no additional workload (NDRAHA et al., 2018). In this tech stack, the data collected can be analyzed and transformed into useful information which will offer a privileged view of all aspects of the production chain, allowing the creation of alert systems and anticipating internal and external crises which would require corrective intervention (BEN-DAYA et al., 2020).

Nowadays, the availability of solutions which enables IoT for the automated monitoring of temperature in the equipment and processes of the FS remains incipient. Since those devices are typically industrial-grade instrumentation (EMERSON, 2022; ENDRESS+HAUSER, 2022; SIEMENS, 2022; YOKOGAWA, 2022), and their acquisition costs are beyond FS' financial capacity, especially for small and medium-sized establishments. Some companies have recently been investing in technologies adjusted to the needs and capabilities of FS, such as SmartSense, which launched a kit with three wireless thermometers and a gateway for USD 800 + USD 65/month (BRL 4,170.80 + BRL 338) (SMARTSENSE, [s.d.]). Unfortunately, most of them require importation, with extra costs and challenges (SmartSense is not sold in Brazil).

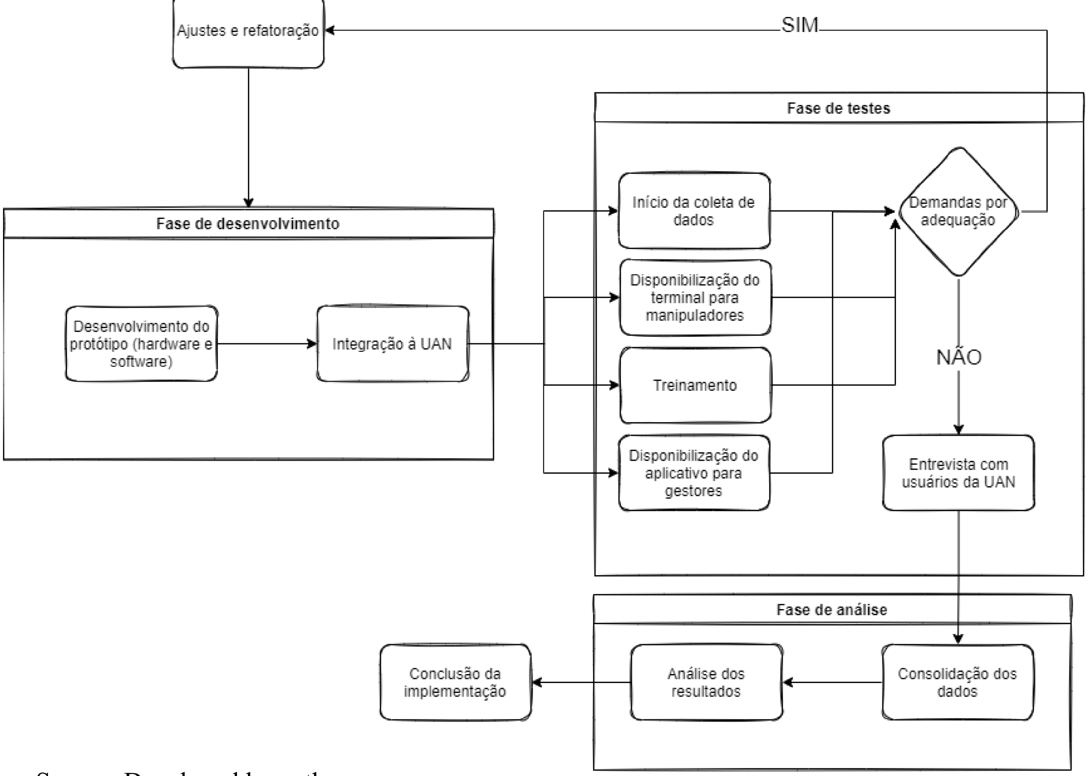
This paper describes the development and evaluation of a low-cost and open-source IoT solution, including devices and systems designed to automate the temperature monitoring of equipment and processes in FS.

2.1.2 Materials and methods

The present work is characterized by a multidisciplinary approach to research by associating knowledge from multiple sources to solve concrete problems and reaching a final product, known as an artifact. In such a type of research, the artifact can be a physical device, an immaterial device, or a composition of both, later being tested in terms of its merits in multiple ways (DRESCH; LACERDA; JR, 2015; ROPES, 2018).

The present study was conducted according to the design science research structure (PEFFERS et al., 2014), consisting of a series of iterative steps: a) identifying and defining the focal problem; b) defining the objectives which the solution must resolve; c) designing and developing the artifact; d) demonstrating that the artifact can be used to solve the focal problem; e) assessing how well the artifact solves the focal problem; f) communicating the research results. Figure 1 describes the flowchart of actions to develop the low-cost IoT platform for FS.

Figure 1 - Flowchart of steps to develop the low-cost IoT artifact



Source: Developed by authors

2.1.2.1 Guidelines for defining the artifact's attributes and minimum requirements

The artifact was developed based on guidelines defined from the scientific and technical literature review and the analysis of FS equipment and routines.

Electronic sensing devices should allow the continuous monitoring and sending of data, via the internet, of the temperature (°C) and humidity (% R.U.) in the equipment present in FS. The artifact should also store measured data history in a robust database and issue alerts when it detects inadequate temperatures, equipment downtime, or when it detects a failure of its own functionality.

The following FS equipment were included in the tests: 3 two openings horizontal freezers (a.k.a., F01, F02 and F03) running 250W/-30ºC, 1 two opening horizontal freezer (F05) running 400W/-30ºC max., 2 single opening vertical fridges (G01 and G02) 150W and 1 heating table running 1.500W.

The device should not compromise the hygienic quality of the meal production process and should be resistant to environmental conditions and procedures performed in the FS. When assembling the device (sensors, microcontroller, circuits, cables, enclosures), priority should be given to inputs available in the national market and subject to purchase from different suppliers.

Temperature sensors should operate, at least, within the temperature range of -35 to 100 ºC. Temperature and humidity sensors with digital output signal would always be prioritized, aiming to suppress the instability in the readings and the need for complementary circuits to reduce noise (MPS, 2016; WTMATTER, 2019).

The NodeMCU microcontroller (Esp-12e Version 3) was defined as the default for the development of the artifact because it combined low cost, open-source license wireless communication embedded through ESP8266, an abundant ecosystem of libraries (NODEMCU, 2018), market availability, and an ample list of compatible firmware (ESP8266, 2018).

Regarding the software and libraries used, priority was given to using ready-made resources with a permissive open-source license, such as Apache or BSD, or non-permissive, such as the GPL (OSI, 2016). All cloud services should preferably be free or have the lowest possible cost.

All systems, except NodeMCU firmware, should be compatible with Linux operating systems running on single-board computers with an ARM 64-bit processor, CPU>=1.4GHz, RAM>=1GB (such as Raspberry Pi 3 Model B+ and Raspberry Pi 4 Model B), and with

Amazon Web Services' t2.micro equivalent cloud instances (lower-cost general-purpose instances on AWS).

Databases should be non-relational (MEIER; KAUFMANN, 2019) for better compatibility with the storage of time series data and to allow a simplified reformulation of the data structure (JAXENTER, 2020). Concerning network security, the integration of the artifact to the FS network should occur without requiring changes to external access rules (or any other firewall change), meanwhile guaranteeing access to data for users outside the local network. Further, all locally installed devices must have a minimum of one access barrier with a password.

The interface made available to the user should be compatible with their activities and should allow them to quickly qualify the status of the monitored parameter, whether it conforms or not.

2.1.2.2 Test environment

The FS in which the artifact was tested belonged to the public educational system, which provided meals to students and employees of the Federal University of Juiz de Fora (Governador Valadares). It serves 850 meals/daily, counting on 7 employees (02 managers and 05 food handlers), operating in a concessionaire management schema, from 6:00 a.m. to 3:00 p.m and becaming open to the public from 11:00 a.m. to 1:30 p.m.

The temperature measurement devices were installed in 07 different FS equipment (freezers, refrigerators, heated distribution counter). The field testing period took 130 days (07/09/2021 to 11/16/2021).

The reference values for issuing alerts were determined by the research team, based on RDC 216 (BRASIL, 2004) for thermal conditioning equipment and on NBR 16401 (ABNT, 2008) for the FS environment. Freezer: Max. -18º C; Refrigerator: Max. 5ºC; Heated distribution counter: Min. 60ºC..

Before the tests, all food handlers and FS managers received training covering the proper knowledge on reading data on the physical panel. FS managers (02 people) received additional training to use the application and the web interface.

Additionally, a website was made available (CAMPOS, 2021) containing information in text, videos, and animations regarding the configurations of the artifacts, using and interpreting the data, identifying problems and solutions, and frequent questions. Finally, a permanent communication channel was created via telephone and the instant-messaging application, WhatsApp (WhatsApp Inc., Mountain View, California) for FS professionals to report their queries and request support in case of intercurrences.

2.1.2.3 Technical evaluation of the artifact during uninterrupted use

The technique for evaluating the artifact consisted of a two-phase test procedure, which were segmented into bench tests and field tests, where the first focused on steps B and C and the latter on steps D and E of the driving logic proposed by (PEFFERS et al., 2014). In both phases, the determining element was long-term stability, aiming to achieve an artifact construction which could operate uninterruptedly, even in the adverse conditions of the FS.

For analysis, the software and hardware elements of the artifact were evaluated in regards to stability during uninterrupted use by gathering information on downtime due to internal failures, downtime due to external failures, and the duration of time to fix failures. Seeking to mitigate confounding factors related to devices downtime, such as the environmental conditions in FS, which are often harsh on the electronic components, an additional device was installed without any protection for the circuits, which allowed the evaluation of the innate resistance of the NodeMCU as well as the differential protection provided by the selected enclosures.

Costs were estimated based on the individual price of each physical component or the price of contracting the service without considering researchers' labor costs. The reference value for each item considered the acquisition cost between June/2020 to June/2021. Cloud infrastructure cost assumed the mean value between June/2021 to November/2021.

2.1.2.4 User evaluation

Food handlers and managers were asked to interact daily with the information collected by the devices until survey application day to determine the users' perception based on a meaningful experience. User satisfaction was evaluated using a self-developed likert-like structured survey applied by researchers composed of four multiple choice questions which addressed the ease of access to information; notifications of incidents via smartphones; the benefits that the implementation of monitoring of this equipment brought to the activities developed; the deployed system's global quality.

Because the FS's routine often assigns a different staff member to survey the equipment's temperature based on daily analysis, staff members were asked to answer only survey questions related to the equipment to which they were assigned.

The collected data were analyzed considering the positive and negative perceptions of the respondents. As the purpose of the survey simply involved the validation of the possibility of achieving the project's objective, without making any inferential analysis, statistical methods were not applied to the collected data (KADAM; BHALERAO, 2010). only descriptive methods were used then.

2.1.2.5 Ethical considerations

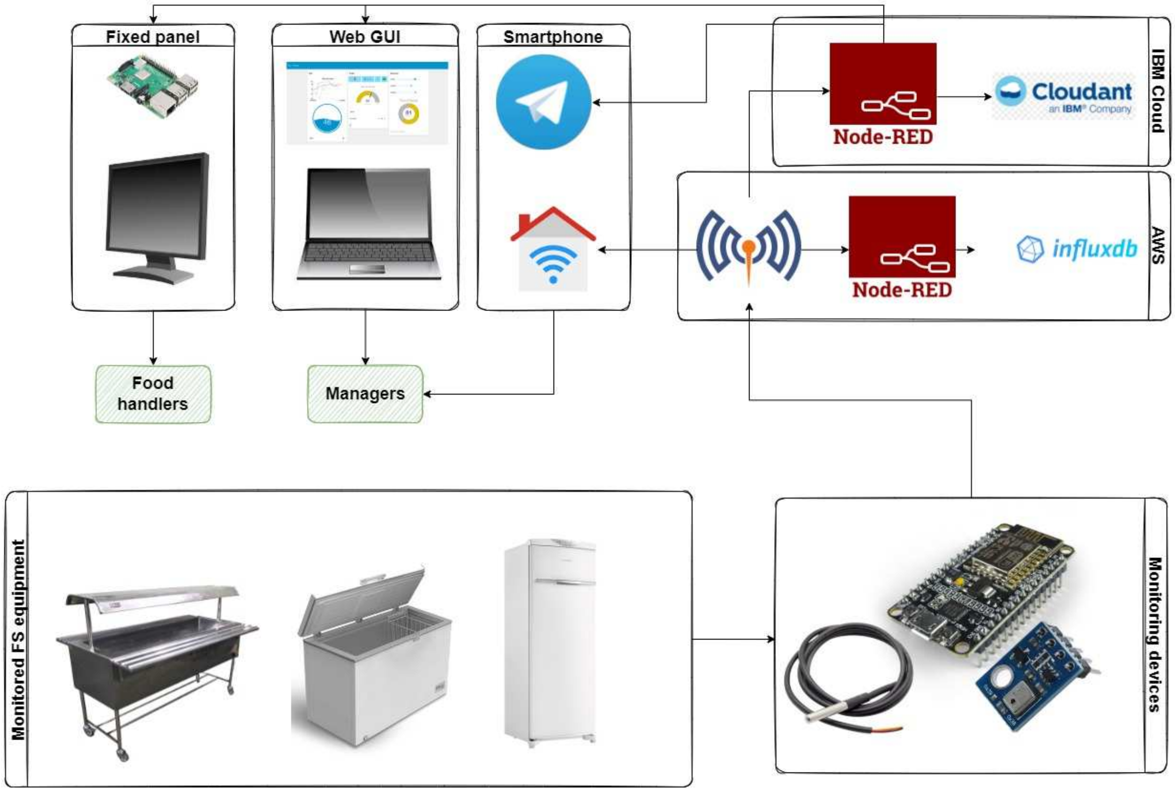
The Ethics Committee in Research approved this project with Human Beings of the Federal University of Juiz de Fora, CAAE 32004720.00000.5147.

2.1.3 Results

2.1.3.1 Artifact architecture

Components and system integration were defined in the schematic view shown in Figure 2 and detailed in the following topics.

Figure 2 - Schematic view of the system architecture



Source: Developed by authors

2.1.3.2 Monitoring devices

Throughout the integration phase onset, some components were tested and discarded due to nonconformities considered unsolvable:

- Metallic boxes: caused a Faraday cage effect that interfered with boards communication;
- DHT11: too short a range (relative humidity: 20% to 90% RH and temperature: 0º to 50ºC) and low accuracy (± 5.0% RH and ± 2.0 ºC);
- AM2301: cost at least four times higher than similar metrological characteristics.

The different monitoring devices tested (detailed in Table 1) used NodeMCU Esp-12e Esp8266 V3 microcontroller (Espressif Systems Co., Ltd) as a basis coupled to DS18B20 (Maxim Integrated Inc, San Jose, California) or AHT10 (Aosong Electronics Co.,Ltd, Guangzhou, China) sensors and support circuitry.

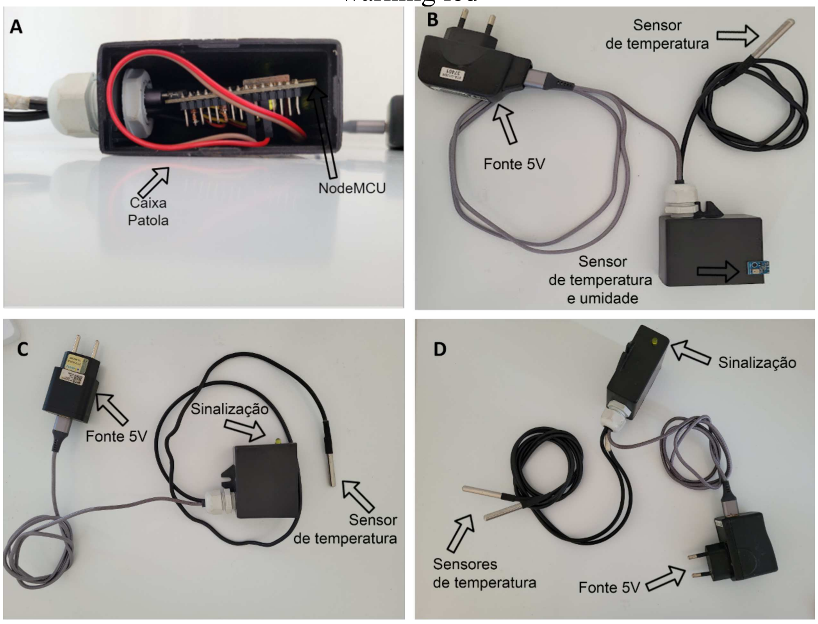
Table 1 - Tested device specs

Id.	**Sensor description**	**Warning agent**	**Purpose**	**Testing site**
A v1	02 DS18B20 stainless and waterproof packaged + Patola PB-046 cage + 5V-1A micro usb	None	Measure temperatures from -55ºC to 125ºC in dry or water site in 02 simultaneous FS equipment02 Freezers (F02 e F03) 02 Fridge (G01 e G02)	02 Freezers (F02 e F03) 02 Fridge (G01 e G02)
A v2	02 DS18B20 stainless and waterproof packaged + Patola PB-046 cage + 5V-1A micro usb	External LED	Measure temperatures from -55ºC to 125ºC in dry or water site in 02 simultaneous FS equipment02 Freezers (F02 e F03) 02 Fridge (G01 e G02)	02 Freezers (F02 e F03) 02 Fridge (G01 e G02)
B v1	01 DS18B20 stainless and waterproof packaged + Intelbras V1100 cage + 5V-1A micro usb	Buzzer	Measure temperatures from -55ºC to 125ºC in dry or water site in 01 simultaneous FS equipment	01 Freezer (F05) 01 Heating table
B v2	01 DS18B20 stainless and waterproof packaged + Intelbras V1100 cage + 5V-1A micro usb	External LED	Measure temperatures from -55ºC to 125ºC in dry or water site in 01 simultaneous FS equipment	01 Freezer (F05) 01 Heating table
C v1	01 DS18B20 stainless and waterproof packaged + AHT10 thermo hygrometer sensor + Modesto CFTV cage + 5V-1A micro usb	Internal LED	Measure temperatures from -55ºC to 125ºC in dry or water site in 01 simultaneous FS equipment + environment	01 Freezer (F01)

Source: Developed by authors

Instead of soldering, drilling, and plate making, device components were joined using removable connections or breadboards and encased in a box without a display or buttons. The device's basic structure with a detailed component list can be seen in Figure 3. The microcontrollers were equipped with a modified version of Tasmota 9.5.0.4 firmware (TASMOTA, 2022).

Figure 3 - Internal and external physical structure of A v2 with its two temperature sensors (DS18B20) A) Internal view common to devices A v2, B v1, and C v1; B) External view of device A v2 with its two sensors for temperature (DS18B20), its power source and warning led



Source: Developed by authors

2.1.3.3 Cloud and systems

All software components (except firmware) were isolated in Docker containers (DOCKER INC;, 2021). Node-RED and a database instance (InfluxDB and Cloudant) were hosted on two different and independent cloud instances provided by AWS t2.micro (Amazon Web Services, Inc., San Francisco, California) and IBM Cloud free tier (256MB ram + 1GB storage) to test the usability of a free-of-charge service compared to a paid one. Due to an IBM Cloud MQTT server incompatibility with Tastmota, HiveMQ was initially used to achieve an entirely free of charge and fully functional version package of cloud services, and Moquitto MQTT was hosted on AWS.

Node-RED (OpenJS Foundation, v. 1.3.2) worked collecting ephemeral data from Mosquitto (Eclipse Foundation, v.2.0.14, San Fracisco, California) into the NoSQL databases (Cloudant in IBM Cloud or InfluxDB in AWS). It also was used for all the back-end and front-end functions for the dashboard and the physical panel, processing raw data and managing notifications to users via the smartphone application, Telegram.

2.1.3.4 Local network security

To ensure local network security in the FS, a unidirectional access policy was defined. MQTT connections were only allowed to be opened by the clients, keeping the routes, protocol, and flow of communication under control. The logical ports opening for external requests were suppressed entirely, and only the MQTT server interacted with the devices inside the FS network (no other cloud services had any FS local access).

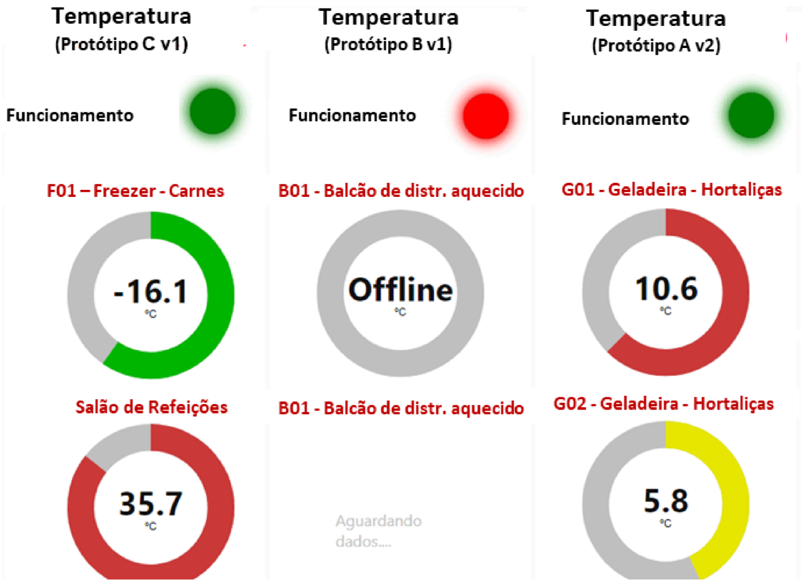
2.1.3.5 Data access channels

The access to temperature data was made available to food handlers through the use of a fixed panel consisting of a conventional 10" monitor and a Raspberry Pi 3B; and to FS managers through both a responsive online dashboard and android app called IoT MQTT Panel (KODAN; PARMAR; PATHANIA, 2020b).

The FS managers were also able to control parameters for issuing alerts through an interface available only on the Android app. However, it was requested that they did not change the temperature setpoint without first notifying the research team.

The interfaces for accessing data collected by the devices are shown in Figure 4 (Node-RED provided dashboard) and Figure 5 (IoT MQTT Panel provided dashboard). The visual elements, such as graphics, texts, numbers, colors, animations which communicated the state of the equipment to the users, presented a simple and representative aspect, following a clear pattern on states of normality (green color), alert (yellow color) and disturbance (red color).

Figure 4 - Graphical interface made available to managers for monitoring information via the web and food handlers via fixed instrument board

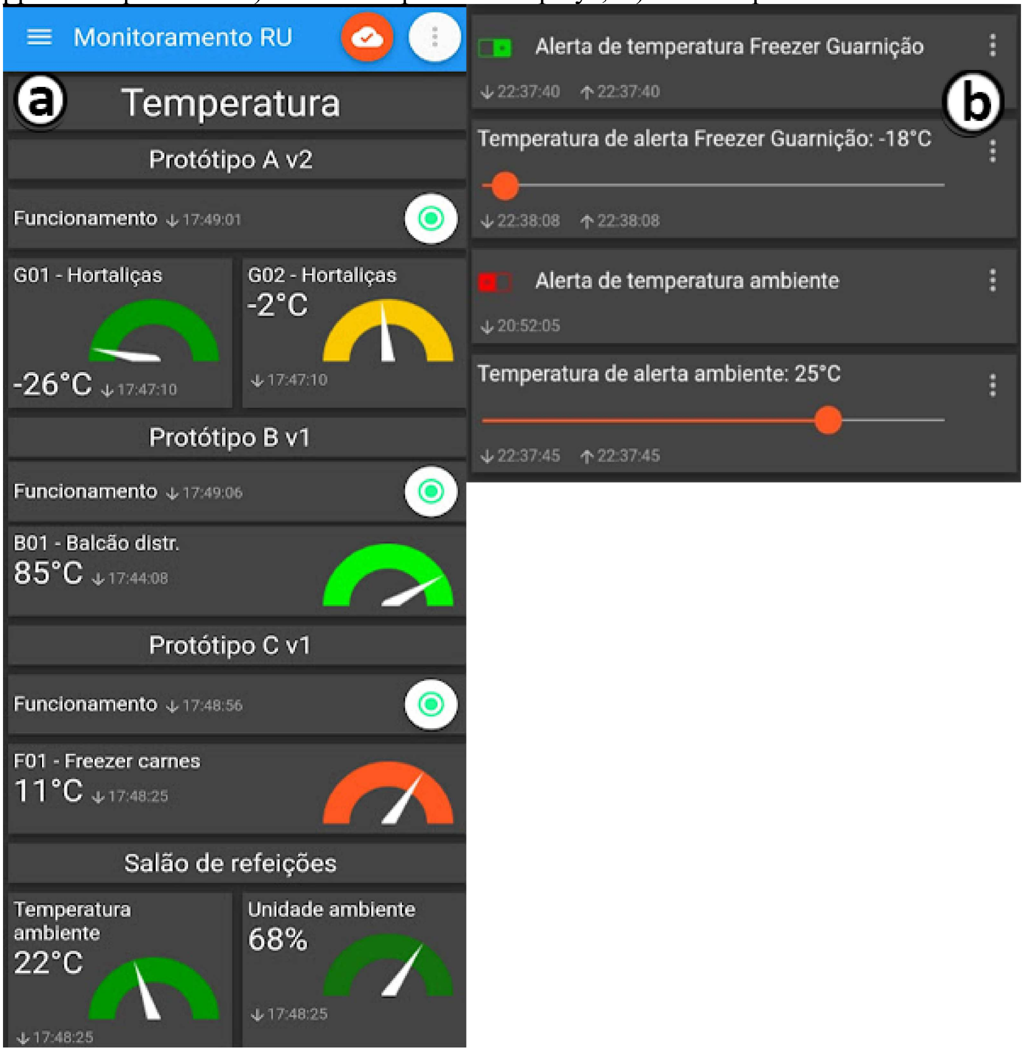


Source: Developed by authors

The fixed panel dashboard was designed for the cafeteria staff, and installed inside production area, providing straight-forward temperature information and alerts from all monitored equipment (Figure 4, devices of the equipment Cv1, Bv1, and Av2). Managers had access to the view of temperature fluctuation from the last four hours (Figure 4, device Bv1) through extra charts.

The dashboards of the cafeteria staff and the managers shared the same visual conception, with a minimalist color palette to recognize states. The top portion showed measured parameters label, device ID, device operating status with a visual indicator (green/red dot), followed by donut charts exhibiting measured values.

Figure 5 - Graphical interface in Brazilian Portuguese provided for FS managers through Android app IoT Mqtt Panel. A) Part of temperature displays; B) A small part of the alert controls



Source: Developed by authors

Possible malfunctions of each device's sensors were signaled by the indication of the term “offline” in the center of the temperature graphs and a complete chart color change to grey (Figure 4, device Bv1), conferring a simple and intuitive way of distinguishing between the possible sources of malfunction through different color patterns.

2.1.3.6 Malfunction notifications

Malfunction notifications were made available to managers and any designated food handlers through Telegram messenger (Telegram FZ LLC, version 1.8.5, Dubai, United Arab Emirates) group chat by a bot. Each occurrence generated a message as well as malfunction clearance.

2.1.3.7 Technical evaluation of the artifact in uninterrupted use

Throughout the field tests phase, none of the device's hardware exhibited signs of malfunction, working stably during the entire period of tests. Some minor changes were made in devices A, B, and D to improve adherence to the scenario specificities by replacing the buzzer with external LEDs. Software and services demanded more pronounced adjustments to maintain all artifacts segments. They are listed in table 2.

Table 2 - Report of occurrences of functioning of the developed artifacts

Event 1	All devices ceased sending information to the MQTT server
Cause	Failure in the service provided by HiveMQ in free tier instances package (IBM Cloud + HiveMQ).
Solution	No solution was found for HiveMQ, and all devices were directed exclusively to the AWS MQTT server.
Event 2	Specific devices were losing communication with MQTT
Cause	FS power outlet presented intermittent malfunction causing plugged devices to turn on and off successfully and activating Tasmota's boot loop automatic procedures, erasing all non-hard coded configurations (including MQTT and wireless credentials).
Solution	Since FS infrastructure maintenance was not an option, Tasmota's source code was modified to disable the boot loop.
Event 3	The dashboard exhibited on the fixed panel presented a 503 error code always when the FS wireless signal dropped out.
Cause	Broken internet signal interrupted WebSocket connection with Node-RED.
Solution	A script in the Raspberry Pi is included to refresh Node-REDs connection in a 60s interval.

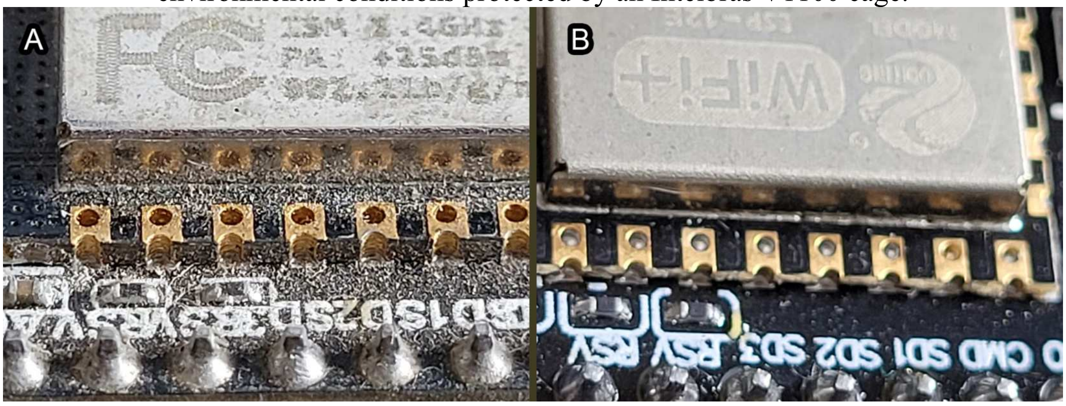
Source: Developed by authorship

All data (1,368,719 records) that went through the Mosquitto was stored integrally into the databases. Both IBM Cloud free instances and AWS t2.micro met the needs of the study splendidly.

When considering Cloud services performance, any benchmarking methodology was applied to compare performances quantitatively because, at least now, all that matters is the long-term stability.

Box suppliers (Patola, Modesto, or Intelbrás) showed the same circuitry condition after visual inspection, indicating that they are equivalent and can be selected according to convenience criteria (such as cost and circuit accommodation capacity). Figure 6 demonstrated the contribution of the adopted enclosures, revealing the presence of terminals with the presence of an oxidative layer and residues in the NodeMCU microcontroller kept without enclosure.

Figure 6 - Comparison between the wear of two NodeMCUs installed on the same UAN for 130 days. A) A NodeMCU fully exposed for 130 days with oxidative layer and residuals over terminal pins; B) Visually intact NodeMCU kept under the same environmental conditions protected by an Intelbras V1100 cage.



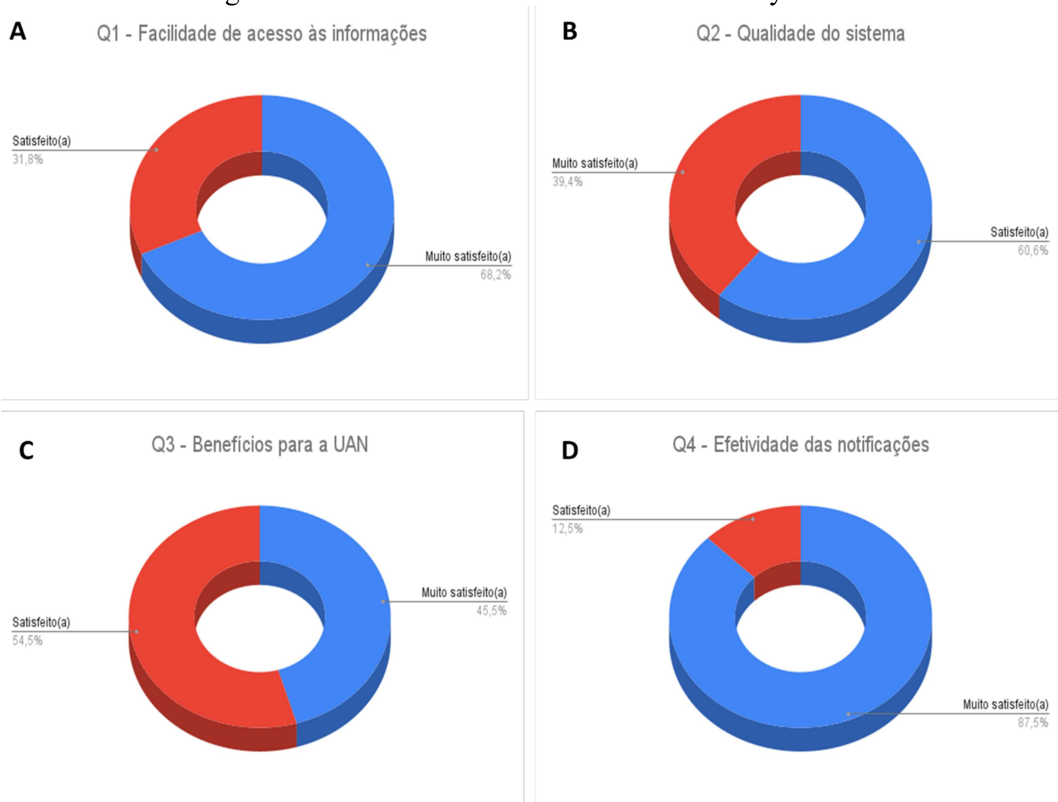
Source: Developed by authors

The costs of the physical components used for the models were: Av1 and Av2 BRL 150.00 (USD 28.55); Bv1 and Bv2 BRL 130.00 (USD 24.75); and Cv1 BRL 140.00 (USD 26.65). The 10" monitor with Raspberry Pi support cost BRL 500 (USD 95.17), and the Raspberry Pi 3b itself cost BRL 600 (USD 114.21). The cost of services for the t2.micro instance in the AWS cloud was BRL 45.37 monthly (USD 8.35/month) (if the instance's capacity was not exceeded). Therefore, the total cost of the artifact, labor cost not included, was BRL 2,064.44 (USD 392.96), of which BRL 1,520.00 (USD 289,33) refered to physical components and BRL 544.44 (USD 103,63) per year for the cloud services.

2.1.3.8 User evaluation

The results of the artifact’s evaluation performed by the users are shown in Figure 7. All users were satisfied or very satisfied with the ease of access to the collected information; event notifications of incidents through smartphones; the benefits that the implementation of monitoring of this equipment brought to the activities developed; the deployed system global quality

Figure 7 - Results of the evaluation carried out by users.



Source: Developed by authors

2.1.4 Discussion

2.1.4.1 Artifact architecture

Considering the main factors that influenced the artifact's constitution (implementation difficulties, maintenance, deadlines, and costs), the architecture promoted a functional arrangement of all hardware, software, and infrastructure elements with satisfactory results.

2.1.4.2 Monitoring devices

The physical device's design sought to evade any permanent or destructive intervention (such as cuts, holes, or welds) to increase the possibility of successive reworks. It was an essential objective because of the implementation challenges and uncertainties faced in a complex multilayered artifact (GALLI; LOPEZ, 2018) and the harsh conditions for electronics regularly found on FS (LI et al., 2012; PARK; KWAK; CHANG, 2010).

Another design choice with significant repercussions was the absence of buttons or displays on the device enclosures, aiming to reduce usage complexity for general users total cost per part. Considering that simplicity contributes to the acceptance of new technologies (UFLACKER; BUSSE, 2007) and also can reduce components' exposure to infiltration risks during regular cleaning procedures in FS which, consequently, increased the devices' durability.

For the logical part of the NodeMCU microcontrollers of the devices, the Tasmota 9.5.0.4 firmware (TASMOTA, 2022), proved to be an advantageous alternative in terms of time and effort compared to an in house firmware development. Despite the loss of complete control of features and optimizations, several benefits can be noted when adopting this pragmatic development philosophy (STOL; ALI BABAR, 2010): fully open source with GPL-3 license, native support for all sensors used in the artifacts and MQTT (including TLS), command execution allowed through multiple interfaces (web server, RX/TX, MQTT), and support of internal scripts to add functionality without a new firmware compilation. An extensive and updated documentation for source code customization is needed (TASMOTA, [s.d.]).

2.1.4.3 Cloud and systems

The use of containers for each system was profoundly beneficial for system architecture, allowing them to be activated, deactivated, updated, replaced, repaired, and restored independently (DOCKER, 2020). In addition, it allowed easy backup and effortless migration between different servers (cloud or local) without the need to install long and problematic lists of prerequisites (LIU; ZHAO, 2014).

The MQTT Mosquitto server provided flexibility, an important feature to meet different network policies previously established in the FS. Regardless of the eventual success in opening ports by a secure bidirectional path using VPN, Reverse Proxy, or equivalent (JAHAN; RAHMAN; SAHA, 2017), those policies required at least a static IP on the FS network. It was found that the FS network had Dynamic IP, which would demand the hiring of other services to make devices accessible for cloud storage (BENOMAR et al., 2021) and reinforce Mosquitto's role on artifact communication structure.

Node-RED played a vital role on the back-end, contributing to keep the stack lean and with a good delivery flow. It offered many of the capabilities, performance, and robustness of Node.js (FERENCZ; JÓZSEF, 2020) with a low-code abstraction layer based on event streams (NODE-RED, 2022). With its flow-based rapid development environment, Node-RED allowed faster system refactoring by reducing complexity (STEVEN, 2020). Despite the limitations of working primarily in a higher level of abstraction, this flow-based no-code approach virtually removes all syntax and runtime as potential errors, with logic remaining as the only factor to be worked, thus reducing the needed labor cost of code maintenance (DI SIPIO; DI RUSCIO; NGUYEN, 2020).

Node-RED also natively allows the construction of responsive graphical user interfaces without requiring proficiency in web development or specialized dashboards software like Grafana (GRAFANA, 2019). It also offers seamless integration with both databases used, Cloudant and InfluxDB (NODE-RED, 2022; O'LEARY; WALICKI, 2021). Those capabilities had an exceptional contribution to the feasibility of the study because they bypassed the need to deal with additional knowledge domains.

Seeking to keep future data analytics aimed at predictive maintenance and discovery seasonal patterns possible, all data (1,368,719 records) that went through the Mosquitto was integrally stored into the databases. This storage strategy is not optimized and was used because the safest option would be not to discard any data. Optimization techniques in time series such as evaluating the relevance of recording, discarding, and compiling the collected data (LAST; KANDEL; BUNKE, 2004) were not the scope of this initial phase of technology validation testing.

When considering Cloud service performance, any benchmarking methodology was applied quantitatively because, at least in regards to the present work, all that matters is the long-term stability.

Even though both solutions have met the study's goal, IBM's adoption is not helpful for a real case scenario. Although IBM Cloud was free of charge for the FS type of use, it could not host a compatible MQTT server, and it demands knowledge of the CI/CD methodology (IBM, 2020; VIRMANI, 2015) to operate even the essential platform functions, setting a learning curve barrier. Furthermore, AWS demanded less effort to maintain system infrastructure despite being paid.

2.1.4.4 Local network security

The complete network design was aimed at avoiding breaches which could allow gate exploit attacks on the local network (AVAST, 2022), thus reducing the risks to the FS if any cloud-hosted system were compromised (CVITIĆ; VUJIĆ; HUSNJAK, 2016). The insertion of new elements with bidirectional internet communication in the network was rejected because of that (BITDEFENDER, 2021; CISO MAG, 2022; CVITIĆ; VUJIĆ; HUSNJAK, 2016).

2.1.4.5 Data access channels

To transform innocuous information into the solution of concrete problems in a feasible way, it was crucial for the users of the artifact (whether managers, food handlers or others) to understand how the channel was built through various sensor-collected data (ROPES, 2018). Therefore, the channels assignment considered the target audience's profile, attributions, costs, and the general context to ensure that everyone had access to information through compatible channels.

Access to temperature resources handled through the use of a secure panel through secure repairs to minimize the costs presented by costs. When analyzing other options, the adopted couple was more affordable and feasible than a regular monitor, a desktop computer, a laptop computer, or even a smartphone/tablet. In other contexts, smartphone adoption would be a convenient solution because it offers a rich interactivity layer and can be potentially money-saving (if the food handlers were required to use their own devices). However, in FS, the introduction of any tactile device represents a hygienic-sanitary risk (KURIYAMA et al., 2021) or the potential loss of productivity due to the personal hygiene procedure every time the food handler interacts with the devices.

Additionally, the Android app available to managers could work as a mini-database, saving the content received in the smartphone's storage completely unlinked from the cloud databases, serving as a way to recover the sensors' recent history even if the whole cloud service was down. This multiplicity of data access channels generates a safe redundancy, boosting artifact robustness (LUCAS-ESTAÑ et al., 2018).

The visual paradigms for the development of each graphic user interface's are aimed at efficient communication, making it possible for the user to detect or even easily notify each other about any adverse situations (HU et al., 2018). The minimalist layout and the strong association between colors and conditions (for instance, red color was only used for alerts) served to avoid visual overcharge when users read the data (KANG; KIM, 2007)

2.1.4.6 Malfunction notifications

Receiving notifications immediately after the system detects an event, even when the device was far from the FS facilities, was one of the main features of this artifact. The exchange of data and information related to the temperature of the equipment and the communication in real-time made it possible for managers to execute a synchronized and coordinated reaction in the face of any possible inadequacies. With this, it is possible to mitigate the risk to public health in the event of power outages or equipment failures, which are especially harmful events when they occur outside the opening hours of the FS. Therefore, the artifact could offer a strong advantage by reducing the losses of raw materials or products resulting from the inadequate thermal conditioning, as such, contributing to the financial and environmental sustainability of the FS (TEHRANI; FULTON; SCHMUTZ, 2020).

The option for messengers as a communication channel for the alerts provided faster access to information when compared to e-mails (JABBAR et al., 2021). Telegram, unlike Whatsapp and SMS, presented a totally free API (TELEGRAM, 2020), which justified its choice and allowed managers to direct notifications to specific groups configured in a simplified way (TELEGRAM, 2022).

2.1.4.7 Technical evaluation of the artifact in uninterrupted use

The signaling of the proper functioning of the artifacts becomes a relevant functionality when considering the intense work routine of the food handlers. Thus, the absence of any mechanism that allows this signaling proved to be inadequate as it did not allow a clear discernment of whether the loss of communication with the device was related to problems with the local network, with cloud services or with the device itself. In this way, visual signaling with LED as standard for all artifacts made it an informative mechanism, with low potential to interfere in the work routine of food handlers.

Although audio signals emitted by the buzzer could attract greater attention from employees (CHAN; NG, 2009), the use of this feature may not be suitable for all environments, since the buzzer may result in over signaling and potentially lead to auditory pollution. However, audio signaling is fully suitable for FS environments where there are no people constantly working in close proximity to the devices. As such, auditory signals are already used in some cold chambers to indicate failures in their operation (NG; CHAN, 2013), or in places where there is no recurrence of problems with spontaneous resolution.

The resistance of the devices to the indoor weather of the FS stems from the physical characteristics of the robust microcontroller circuits, the , and the absence of displays and adjustments, which act as points of contamination during operation. In general, the environment of the food services contains a high volume of humidity and vapors (ARAÚJO et al., 2020; SILVEIRA, 2018), which can contribute to equipment damage. Additionally, the equipment of these establishments must be subjected to strict and frequent hygiene procedures to comply with the provisions of current legislation. Accordingly, technical adjustments were made in the various components of the devices which resulted in the equipment being properly adjusted to the operating conditions.

The perception of technical flaws during the development phase of new products and technologies is expected and helps the development team resolve existing situations. Although some of the failures that occurred had the potential to completely interrupt the overall functioning of the set, the solutions which were executed were relatively simple. It is worth noting that these adaptations were not motivated by inadequacies inherent to the artifact, but rather by the infrastructure of the FNU. This fact reinforces the positive result both in the robustness of what was developed and in the inherent malleability that the artifact offers.

The lack of failures during the use of the IBM Cloud evidenced the potential for free services to be used for the implementation of IoT technology. In this study, it was demonstrated that the use of Node-RED and Cloudant in the IBM Cloud infrastructure has the potential to reduce the cost of the artifact, thus contributing to their accessibility for FS establishments. In addition, new users and developers may find greater interest in using platforms with free services, since, as in the case of HiveMQ, these services reduce the learning curve to use the technology as part of companies' strategy to retain potential customers coming from more complex paid services (YAN; WAKEFIELD, 2018). All privacy-important services may differ in relation to guaranteed coverage for customers who do not pay for any protected use benefits, in relation to the privacy of generated data, such as the Eclipse Foundation's free service *(ECLIPSE FOUDATION, 2022)*. In this way, during the selection of free services, special attention must be given to a greater use and potential that provides uninterrupted operation.

The cost of the whole artifact is an essential topic during technical evaluation which defines if this technology is accessible to FS entrepreneurs, especially the smaller FS units struggling with the impacts of the ongoing COVID-19 pandemic (ABRASEL, 2021). On an annual basis, total expense for implantation and maintenance of the artifacts in six FS equipment (not including labor cost) was shown to be 18 times cheaper (BRL 55,000.00 vs. BRL 2,064.44) than its equivalent industrial solutions provided by large companies like Emerson Electric, Siemens AG, Endress+Hauser, and Yokogawa Electric (EMERSON, 2022; ENDRESS+HAUSER, 2022; SIEMENS, 2022; YOKOGAWA, 2022). It is noteworthy that the available automation solutions usually have costly, overdone for FS, certifications to ensure performance and durability within industry standards, which encumbers the cost.

2.1.4.8 User evaluation

Although the applied technical evaluation did not identify failures in the components during the test period, obtaining insights from the experience of final users in the field is a powerful instrument for evaluating the general quality and anticipating potential problems (BOTELHO et al., 2014). Because of this, the development of technological products should not be limited to the creation of an artifact itself (HOLMSTRÖM; KETOKIVI; HAMERI, 2009); the product should also be linked to the perception of the added value of the end-user, who will act as a final evaluator (VAN KLEEF; VAN TRIJP; LUNING, 2005).

Although evaluation by end-users is crucial, it is possible to find similar work on the IoT development for FS (JABBAR et al., 2021; LAKSHMI NARAYAN; KAVINKARTIK; PRABHU, 2019; SAHU et al., 2021; SHIPLEY; FAVIER, 2019) limited to the development of the technology itself, without entering into the users' impression, unlike the present study. Therefore, all efforts had to be directed beyond technical formalities and reach the final user in a meaningful way (JOHNSON, 2020).

One of the main points to ensure the effectiveness of the artifact in the context of FS through user perception was that any information collected by the devices had to be accessible for FS employees in terms of form and content (HOLMSTRÖM; KETOKIVI; HAMERI, 2009; JOHNSON, 2020). In this way, the positive expression of users about the ease of access to information and also the functionality that ensured the sending of messages endorsed the technical decisions associated with the design, and reduced losses due to inadequate storage in the FS.

The positive perception of staff about the benefits of incorporating technology at the UAN may have gone beyond the automation of the temperature measurement process, which contributed directly to meeting the legal requirements established by legislation, such as defined in RDC 216 the cooling control, ultimate freezing temperatures and display temperature of ready-to-eat foods (BRASIL, 2004). These positive responses also result from changes related to the management of the physical structure and operation of the FS. For example, as the pieces of equipment started to be continuously monitored and transmitted information every 60 seconds, it was possible to identify the malfunction of three pieces of two freezers and one refrigerator during the artifact's presence in FS establishment. In addition, after installing the devices, it was possible to trace the heating curve of the heated distribution table, permitting a more economical operation point and, consequently, sparing the electrical bill. It seems reasonable to consider that the expanded capacity to easily monitor several equipment at once is greatly indicative of genuine satisfaction on part of those who operated the artifact during testing (BOKSBERGER; MELSEN, 2011).

Although a degree of approval has already been established for the artifact's performance at the FS establishment, it was necessary to verify whether users judged overall system quality. As the perception of product quality is seen in the literature as something that varies according to the socio-economic aspects of individuals (AGYEKUM; HAIFENG; AGYEIWAA, 2015), the positive impressions about the overall quality of the installed devices was considered positive by both the cafeteria staff and the managers of the FS establishment. This further serves to ratify the artifact's potential in its objective to contribute to the activities of the FS.

2.1.5 Conclusions

In this study, the primary conditions to contribute to the successful digital transformation of FS were achieved, with a successful implementation of IoT devices and systems capable of automating the monitoring of temperature, humidity, and electrical parameters of different equipment present in FS. Compared to the one available on the market, the developed artifact had a low cost and proved robust in the physical resistance, and functioning tests carried out in the field. In addition, users positively evaluated the artifact in all aspects assessed.

The study faced limitations regarding sampling, and however it did not affect its operational result, that limitation decreases its external validity. Further studies are suggested on the impacts of artifacts on a more significant number of FS and belonging to different segments in pursuit of a large-scale validation. New studies are still needed to improve the developed artifact on data storage for long-term continuous operations. Another suggested feature to be tested in new studies is the addition of the notification system directly into the Android app instead of Telegram through the paid version of the IoT MQTT Panel, applying data analysis methodologies to the collection process for structuring predictive maintenance methodologies based on the collected data.

The results available in this study demonstrate that it is possible to build a technological solution for this FS niche at a fraction of the cost of the generally industry-oriented commercial solutions. This artifact also has an important social function in the development of scientific knowledge and public health. The first aspect arises from the fact that all the knowledge produced in this article is made available to the academic community and the general public in an open-source package so that it can be freely replicated and benefit a larger population of FS businesses, including the numerous small establishments that demand accessible technologies. From this dissemination, there is still the second contribution that refers to the improvement of the temperature control procedure in FS, which directly contributes to the promotion of public health through the provision of meals in hygienic and adequate sanitary conditions to the population.

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3 CONCLUSÃO

Neste estudo, as condições básicas para contribuir de forma bem-sucedida para a transformação digital das UANs foram alcançadas através do desenvolvimento de toda a tecnologia necessária, desde os dispositivos físicos até os softwares operando na nuvem. Os dispositivos e sistemas de implementação de IoT desenvolvidos são plenamente capazes de automatizar o controle de temperatura, umidade de diferentes equipamentos presentes em UANs. O artefato desenvolvido apresentou baixo custo frente aos dispositivos disponíveis no mercado, demonstrando ser robusto nos testes de resistência estrutural e de funcionamento que foram realizados em campo. Além disso, os usuários avaliaram positivamente o artefato em todos os aspectos consultados.

O estudo apresentou limitações quanto a amostragem e mesmo que isso não afete o resultado final, acaba diminuindo a validade externa. Portanto, sugere-se novos estudos sobre os impactos dos artefatos em um maior número de UANs, avaliando o artefato em novas unidades e em diferentes segmentos em busca de uma validação em larga escala. Novos estudos são necessários para otimizar o armazenamento de dados para operações contínuas de longo prazo. Outras recomendações são estudos adicionais para avaliar o sistema de notificações diretamente no aplicativo utilizando a versão paga do IoT *MQTT Panel* no lugar do Telegram e aplicação de metodologias de análise de dados ao processo de coleta para estruturação de metodologias de manutenção preditiva baseada nos dados coletados.

Este artefato possui ainda uma importante função social, tanto em termos de desenvolvimento do conhecimento científico quanto promotor de saúde pública. O primeiro aspecto decorre do fato de todo o conhecimento produzido neste artigo ser disponibilizado à comunidade acadêmica e ao público em geral de forma irrestrita, para que seja replicado e beneficie o segmento da alimentação coletiva, incluindo os inúmeros estabelecimentos de pequeno porte que demandam por tecnologias acessíveis e desenhadas para suas particularidades. A partir desta difusão tem-se a contribuição para a melhoria do procedimento de controle da temperatura em UANs, o que contribui diretamente a promoção da saúde pública por meio do fornecimento de refeições mais adequadas à população com melhor controle de condições higienicossanitária.

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APÊNDICE A – INTERFACE DO SITE DISPONIBILIZADO AOS MANIPULADORES DE ALIMENTOS E GESTORES DA UAN

Figura 8 - Interface do site disponibilizado aos manipuladores de alimentos e gestores da UAN contendo informações relacionadas ao funcionamento dos dispositivos desenvolvidos. Fonte: autores

Fonte: Autores

APÊNDICE B – VISÃO GERAL DOS DISPOSITIVOS INSTALADOS NOS EQUIPAMENTOS DA UAN

Figura 9 - Visão geral dos dispositivos instalados nos equipamentos da UAN. A) Dispositivo A v2 monitorando dois equipamentos simultaneamente; B) Dispositivo A v2 e B v2 em operação nos freezers F01 e F05 respectivamente; C) Monitoramento do freezer F02; D) Sensor de temperatura inserido diretamente na água do balcão de aquecimento; E) Visão da fixação simples da instalação do dispositivo A v2

Fonte: Autores

APÊNDICE C – QUESTIONÁRIO APLICADO A TODOS OS USUÁRIOS

Preencha este formulário com sua opinião pessoal sobre cada um dos equipamentos e as funcionalidades apresentadas. Caso não tenha uma opinião sobre a questão, basta assinalar **Indiferente.** Caso não tenha tido contato com o equipamento ou não deseje se manifestar, basta assinalar **Não sei**.
Este questionário é anônimo e nenhum dado nominal será revelado.

	No que se refere à facilidade de acesso às informações referentes ao equipamento	Em relação ao uso do sistema implantado para monitorar esse equipamento, você está	Com relação aos benefícios que a implantação do monitoramento desse equipamento trouxe para a UAN, você está	Como você avalia as notificações de ocorrências via aparelho celular
Balcão de distribuição aquecido	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)
Freezer guarnição e saladas	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)
Freezer carnes e opção vegetariana	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)
Refrigerador 1	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)
Refrigerador 2	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)
Freezer carnes 4	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)
Freezer carnes 5	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)	☐ Não sei ☐ Muito satisfeito(a) ☐ Satisfeito(a) ☐ Indiferente ☐ Insatisfeito(a) ☐ Muito insatisfeito(a)

APÊNDICE D – TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

UNIVERSIDADE FEDERAL DE JUIZ DE FORA

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Gostaríamos de convidar você a participar como voluntário(a) da pesquisa "**Uma nova tecnologia a favor da saúde coletiva: desenvolvimento de dispositivos para integrar Unidades de Alimentação e Nutrição à internet das coisas**". O motivo que nos leva a realizar esta pesquisa é a necessidade de se desenvolver e avaliar novas tecnologias para instrumentação tecnológica da Unidades de Alimentação e Nutrição. Nesta pesquisa pretendemos avaliar um conjunto de dispositivos conectados à internet que viabilizam o monitoramento de parâmetros das UANs a distância, assim como a interface gráfica que permite sua operacionalização.

Caso concorde em participar você testará o conjunto tecnológico desenvolvido e você responderá, anonimamente, um questionário no qual informará eventuais problemas que identificar na nova tecnologia desenvolvida. Além disso, será entrevistado quanto a percepção de facilidade de uso e outros aspectos do conjunto tecnológico desenvolvido. Ao participar desta pesquisa você será exposto a riscos mínimos: a possibilidade de identificação dos participantes, bem como, alguma sensação incômoda ou de desconforto em relação às perguntas e temáticas abordadas durante a entrevista. Mas, para diminuir a chance desses riscos acontecerem, adotaremos medidas protetivas como realização da entrevista em local apropriado e reservado. Além disso, as avaliações serão realizadas no momento que você estiver disponível, visando prevenir riscos de aspecto psicológico, como aborrecimentos e sentimento de impotência em decorrência talvez da impossibilidade de responder ao questionário e receio em responder alguma pergunta do questionário. Também garantimos o sigilo e a privacidade das informações prestadas, pois não haverá divulgação de dados individuais, apenas os resultados relativos ao grupo de pesquisados. A pesquisa pode ajudar, em médio e longo prazo, para a disponibilização de novas tecnologias para serviços de alimentação.

Para participar deste estudo você não vai ter nenhum custo, nem receberá qualquer vantagem financeira. Apesar disso, se você tiver algum dano por causado pelas atividades que fizermos com você nesta pesquisa, você tem direito a indenização. Você terá todas as informações que quiser sobre esta pesquisa e estará livre para participar ou recusar-se a participar. Mesmo que você queira participar agora, você pode voltar atrás ou parar de participar a qualquer momento. A sua participação é voluntária e o fato de não querer participar não vai trazer qualquer penalidade ou mudança na forma em que você é atendido (a). O pesquisador não vai divulgar seu nome. Os resultados da pesquisa estarão à sua disposição quando finalizada. Seu nome ou o material que indique sua participação não será liberado sem a sua permissão. Você não será identificado (a) em nenhuma publicação que possa resultar.

Este termo de consentimento encontra-se impresso em duas vias originais, sendo que uma será arquivada pelo pesquisador responsável e a outra será fornecida a você. Os dados coletados na pesquisa ficarão arquivados com o pesquisador responsável por um período de 5 (cinco) anos, e após esse tempo serão destruídos. Os pesquisadores tratarão a sua identidade com padrões profissionais de sigilo, atendendo a legislação brasileira (Resolução Nº 466/12 do Conselho Nacional de Saúde), utilizando as informações somente para os fins acadêmicos e científicos.

Declaro que concordo em participar da pesquisa e que me foi dada à oportunidade de ler e esclarecer as minhas dúvidas.

Governador Valadares, _________ de __________________________ de 20___.

__________________________________ __________________________________

Assinatura do Participante — Assinatura do (a) Pesquisador (a)

E-mail: leandro.cardoso@ufjf.edu.br

Rubrica do Participante de pesquisa ou responsável:_____________________
Rubrica do pesquisador:___________

Pesquisador Responsável: Leandro de Morais Cardoso
Endereço: Rua Manoel Byrro, 241 - Vila Bretas, Governador Valadares
Fone: (31) 98764-2650 ou (33)3301-1000 R. 1560

Em caso de dúvidas, com respeito aos aspectos éticos desta pesquisa, você poderá consultar:
CEP - Comitê de Ética em Pesquisa com Seres Humanos - UFJF
Campus Universitário da UFJF
Pró-Reitoria de Pós-Graduação e Pesquisa
CEP: 36036-900
Fone: (32) 2102- 3788 / E-mail: cep.propesq@ufjf.edu.br