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Address
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Specialized Partnerships in Sustainable Food Systems and Food Sovereignty,
Faculty of Organic Agricultural Sciences,
University of Kassel,
Nordbahnhofstrasse 1a,
D- 37213 Witzenhausen,
Germany.

Telephone: + 49 5542 98 -1621
Fax: + 49 5542 98 -1604

Email: *editorialboard@fofj.org*

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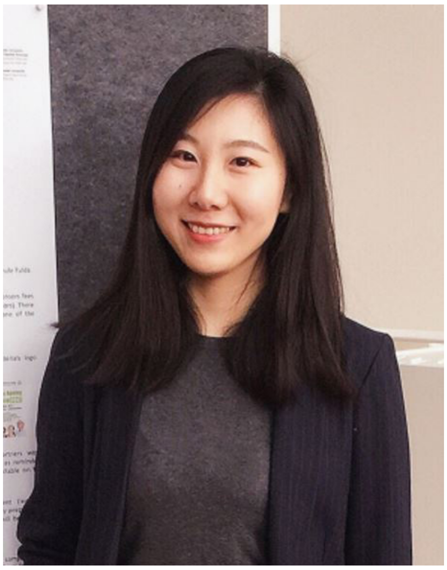
Editorial

A Growing International Consensus: Promoting Sustainable Food Systems



Dr. Xin Qi was awarded a Ph.D. (Dr. agr.) from the University of Kassel, Germany, in August 2021 for a dissertation on "Green food consumption". She completed her master's degree in the master program "International Food Business and Consumer Studies" from the University of Kassel and Fulda University of Applied Sciences, Germany. Dr Qi's research interests are consumer behaviour of environmentally friendly food products, green food, sustainable food consumption, and agricultural product marketing.

Zero Hunger, one of 17 United Nations Sustainable Development Goals (SDGs), aims to end hunger and achieve food security and improved nutrition by 2030 while promoting sustainable agriculture (1). As the year 2030 approaches, global hunger increases (2). Meanwhile, COVID-19 is still rapidly spreading worldwide and affecting humankind at an unprecedented scale (3). COVID-19 pandemic restrictions destroyed the whole agri-food chain and people's lives, livelihoods, and nutrition, especially for the most vulnerable population groups. According to The State of Food and Agriculture 2021 (2), a report from the UN's Food and Agriculture Organization (FAO), 2.37 billion people were without food or unable to eat a healthy, balanced diet regularly 2020.

Facing the situation that the global food system is difficult to operate effectively and can not continuously provide nutritious food for the global population, countries are taking more decisive measures to change the pattern of global food production and consumption and jointly promote the transformation of the global food system. The international consensus is growing that it is crucial to transform the agro-food system into a more efficient, resilient, inclusive and sustainable direction, and the need for high-level research on agriculture, food production, and agricultural sustainability is unprecedented (2). The transformation of the global food system is a complex systematic project (4). No country or organization can deal with the global challenges in food and agriculture alone. The pandemic has made governments worldwide profoundly aware of the vulnerability of the global food system, but it has also made countries deeply mindful of the importance of global unity.

Food system sustainable reform is critical to many global agendas, while it ultimately depends on the action at the national and local levels. There are various agricultural systems worldwide, and the food culture of multiple countries is rich and

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colourful. The global transition process will require sustaining a long-term commitment and international cooperation. It is crucial to use complementary advantages and endowment utilization between developed and developing countries to promote a sustainable global food system.

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Preliminary assessment on drought tolerance of oil palm in semi-arid area

Muhamad Azhar Abdul Wahid[1,*], Nurul Fatiha Farhana Hanafi[1], Mohd Nasruddin Mohammad[1], Muhammad Farid Abdul Rahim[1], Siti Habsah Roowi[1], Mohd Azinuddin Ahmad Mokhtar[1], Mohd Shahkhirat Norizan[2] and Mohd Nizar Khairuddin[2]

[1]Department of Planting Material, FGV Research & Development Sdn Bhd, PPP Tun Razak, PO BOX 11, Jerantut, Pahang, Malaysia.
[2]Department of Agronomy and Strategy Crops, FGV Research & Development Sdn Bhd, PPP Tun Razak, PO BOX 11, Jerantut, Pahang, Malaysia.

* Corresponding author: azhar.aw@fgvholdings.com

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Drought tolerance, dry region, oil palm breeding, performance index, Peninsular Malaysia

Evaluating oil palm growth performance and their corresponding effect on drought is crucial for proper parental selection. The parent palm that has drought tolerance characteristics has less affect on oil yield production, thus, highly potential as future planting material for dry region areas. A study using split-plot with four replications in a randomized complete block design (RCBD) was conducted. All 19 progenies were evaluated and interaction effects were estimated using split-plots analysis. Among all progenies, PB29 showed the highest average production in terms of vegetative growth and oil yield. This was clearly seen on the first year of harvesting (2017), where fresh fruit bunch (FFB) of PB29 was reaching 12.42 t/ha, while in the second year of harvesting (2018), showed increment of 5 t/ha, with a total annual FFB yield of about 17.94 t/ha. Drought tolerance trait is a major improvement if it can be incorporated into new planting material of oil palm. It can widen the range of suitable land selection for plantation thus increasing the possibility to expend oil palm in marginal regime areas. The new breed must possess two characteristics which are, the ability to tolerate a drought condition as well as excessive water supply (seasonal climate), and produce high oil yield.

1. Introduction

Oil palm (*Elaeis guineensis*) is by far the most efficient oil producing crop in the world. It is grown mainly in South-East Asia, Malaysia and Indonesia. In these growing regions, the annual rainfall varies from a well distributed 2000 mm to a seasonal deficit of less than 1500 mm, which can be compensated with irrigation. However, the uneven rainfall distribution is amongst the major contributing factors affecting high oil palm yields (Goh et al., 2000). For optimum yield, the minimum rainfall required is around 1500 to 1800 mm/ year-1 with an absence of dry season and an evenly distributed sunshine exceeding 2000 h year^{-1} (Bakoume et al., 2013). Meanwhile, the mean maximum temperature range between 29 to 33°C and minimum temperature between 22 to 24°C favour the highest oil palm bunch production (Corley and Tinker, 2003). A study in Southern Thailand indicates that dry seasons occur within four months in a year and have caused oil yield reduction by 25% - 35% (Corley et al., 2018, Duangpan et al., 2018). Periodic dry periods in January-March and June-Augustcommonly occur in the inland areas of the peninsular Malaysia (Hazir et al., 2018). Even in the wet tropics, water availability for the oil palm during dry periods can be limited, which creates stress and a wide range of negative effects on productivity.

As demand for vegetable oil increased globally (Khatiwada et al., 2021), cultivation expansion into regions with a significant annual dry season are inevitable. Thus, introduction of drought tolerant planting material is a way to move forward as the tolerant crosses have higher yield than the susceptible crosses (Nodichao et al., 2011). In Malaysia, the oil palm was introduced to northern Peninsular of Malaysia, a monsoonal-type climate region, with distinct long, dry seasons, where rainfall is less than 1500 mm and poorly distributed throughout the year. These were aggravated by limitation of soil's water holding capacity and relatively shallow roots . Soil type and rainfall form the basis of the site yield potential (Woittiez et al., 2017). Areas with a pronounced drought for three months ormore have an inherent effect to yield potential that limits fresh fruit bunch (FFB) production which exacerbates by excessive rain in the following wet months. Hence, irrigation is crucial in reducing the dry period effects.

Oil palm planting material is produced by crossing thick-shelled dura palms with shell-less pisifera palms, to produce the tenera fruit that has a thin shell but thick oil-bearing mesocarp, which has a higher oil yield than the dura. A single pisifera can yield sufficient pollen to produce several million seeds per year, so it is important to identify the best pisifera by progeny testing (Corley et al., 2018). Therefore, finding the oil palms with different responses under drought conditions must be based on their genetic origin, cross-type, partially independent from its production potential, since genetics is the best alternative to identify high-performing crosses and parents (Méndez et al., 2012). Previously, Suresh et al. (2008) has ranked three dura background with drought tolerant character; Zambia (ZS) > Guinea Bissau (GB) > Tanzania (TS). While Méndez et al. (2012) has indicated 4 crosses, L430T x L404T is tolerant, L2T x D118D moderate tolerant, and meanwhile L10T x D118D and L2T x D10D are susceptible. Interestingly, from FGV trials, the L2T, L404, D10D, D8D, L270D, L404D, UR333/5 and UR295/3 have outstanding performance in Serting Hilir Trial 4 & 5 (a moderate to low rainfall regime). However, FGV, lack in performance data of various oil palm progenies under the drought condition.

In order to continue searching for new genotypes that aretolerant to water deficit, it is crucial to establish a new trial by incorporating various genetic backgrounds in areas where conditions are less favourable for palm growth. The aim of this study is to assess the best crossing palm with drought tolerant progenies in which the effect of yield reduction is minimised.

2. Materials and Methods

2.1. Materials and study area

Selection of planting materials is based on four criterias: (1) Origins ie. AVROS, La Me, and Yangambi; (2) Potential tolerance lineage from previous reports; (3) FGV Advanced materials; and (4) tenera clone materials. A total of 19 progenies were selected including three standard crosses namely SC11, SC12 and SC7b (Table 1). The trial received the standard fertiliser dressings. The study was conducted at FGVAS Chuping, Perlis station that had prolonged dry weather and lower rainfall. This area was categorised as one of the driest places in Malaysia with annual rainfall lower than 1500 mm.

2.2. Experimental Design

Split plot with four replications in a randomized complete block design (RCBD) was done by assigning two levels of irrigation with and without as main block. While in subplot, nineteen progenies were evaluated and their interaction effects with and without irrigation were analysed. The trial site is generally a flat terrain that was previously planted with sugarcane. The field management are following the standard estate and fertilizer practices. Rainfall data was collected in the plot area using rain gauge for four consecutive years from 2015 until 2018. The other information of trial plot has been summarised in Table 2.

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Table 1. The list of nineteen progenies involved with the respective parents

Progeny Code	Female		Male
FC5337	ARK (IRHO)	x	ML (Yangambi)
FC5576	ARK (IRHO)	x	1931 (NPM)
FC5579	CEB (IRHO)	x	CKP (AVROS)
FC5635	GKN (Banting-NPM)	x	TT3 (Yangambi)
PB 6	GKN (Banting-NPM)	x	ML (Yangambi)
PB14	EN13 (IRHO-NPM)	x	GEL (AVROS)
PB15	C2 (IRHO-NPM)	x	ML (Yangambi)
PB16	J4 (IRHO-NPM)	x	GMH (Yangambi)
PB21	N1 (IRHO-NPM)	x	GMH (Yangambi
PB22	C6 (Banting-NPM)	x	GMH (Yangambi)
PB29	FOP (Banting-FGV)	x	ML (Yangambi)
PB36	FQG (IRHO)	x	TT38 (Yangambi)
PB38	FGO (IRHO)	x	TT38 (Yangambi)
PB80	FGV clone 1 (FGV)	x	ML (Yangambi)
PB88	FGV clone 2 (FGV)	x	ML (Yangambi)
PB91	FGV clone 3 (FGV)	x	GMH (Yangambi)
SC 7b	FD1 (Kulai)	x	ML (Yangambi)
SC11	J2 (IRHO)	x	BAE (La Me)
SC12	J2 (IRHO)	x	TT3 (Yangambi)

*parentheses show the origin of the parent palm used in the breeding program

Table 2. The general information of trial plot that has been using in the experiment

Location	FGV Chuping , Perlis, Malaysia
Area available	23.0 ha
Terrain	Flat – Moderately Undulating
Previous crop	Sugar cane
Soil type	Chuping and Dampar Soil Series
Planting material	19 Progenies
Experimental design	Split plot design irrigation as main plots and progenies as subplots
Plot size	4x4 center recording palms (without border palm)
No. of replication	4
Irrigation technique	Drip irrigation, 250 L/palm/day
Planting density	148 / ha

2.3. Vegetative measurement

The vegetative growth was measured for every individual palm for all replicates. The vegetative data collected includes girth size, palm height, leaf width and length, petiole cross section, frond length and canopy length, by using measuring tape. The data was collected for every sixth months after three years of planting.

2.4. Fresh fruit bunch yield

The FFB yield census were conducted four times a year for each palm after three years of planting. The bunch weight measurement was performed thrice (three FFB for every palm) to obtain the mean of bunch weight and FFB yield (t/ha). Data for bunch number for each palm was measured four times a year.

2.5. Performance Index (PI)

Performance index contains several parameters including; fresh fruit bunch (FFB), bunch number (BNO), average bunch weight (ABW), rachis length (RL), leaflet number (LNO), petiole cross section (PCS), leaf area (LA), leaf dry weight (LDW) and frond dry weight (FDW).

2.6. Statistical analysis

All collected data were subjected to one-way analysis of variance (ANOVA) using SPSS (Version 20). A Tukey HSD of all pairwise comparisons for individual mean values by plots was performed to determine which plot means were significantly different from oneanother. All statistical analysis and differences were evaluated at 5% probability level.

3. Results

The trial was planted on 2014 with plot density at 148 palms/ha. Precipitation data around the plot was recorded from 2015 until 2018 at 1363.58, 1147.70, 1434.8 and 1318.3 mm/year, respectively (Table 3). This rainfall data in the plot area indicated lower precipitation compared to other locations of peninsular Malaysia at 2000 mm to 3000 mm/year (Saimi et al., 2020). Three progenies have higher PI values compared to standard cross (SC7) which are PB16, FC5579 and PB29 with values of 74%, 76% and 89%, respectively (Figure 1). Among these three progenies, PB29 has the highest in vegetative growth and yield. The majority of progenies showed lower PI compared to SC7, with the lowest PI is PB14 at 18%.

Table 3. The rain gauge data has been recorded for four consecutive year from 2015-2018 in the study plot area

	Rain gauge (mm)			
Month/Year	**2015**	**2016**	**2017**	**2018**
Jan	2.40	24.00	170.5	185.6
Feb	0.0	7.1	4.1	0
Mac	12.4	0	150.2	1.8
April	100.4	86.6	210.7	38.6
May	136.6	206.7	142.4	156.7
Jun	67.0	58	123.0	121.6
Jul	168.7	92	67.2	205.5
Aug	169.2	84	124.0	50.7
Sept	212.6	175.5	124.0	182.5
Oct	129.4	180.6	124.0	174.6
Nov	238.3	147.2	124.0	58.1
Dec	126.6	86	70.7	142.6
Sum	1363.58	1147.70	1434.8	1318.3

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The plot area was well managed to reduce environmental effects such as weed competition for fertilizer, bare soil cropping, antitranspirants, cropping with other palms and diseases (Figure 2A). As shown in Figure 2B, PB29 is no doubt the best performer for FFB yield even in a drought area. These progenies have high potential to exploit further to produce a more susceptible drought plant material in the near future.

PB29 was selected for further statistical analysis by comparing with control progeny, SC7. As a result, FFB yield (t/ha) between PB29 and SC7 shows an increase in oil yield up to 20% than control during the first year after planting at 2.14 t/ha and higher increment recorded on the second year of drought up to +38% at 17.94 t/ha of FFB (Table 4).

4. Discussion

High PI of the three progenies (PB16, FC5579 and PB29) are contributed to high bunch number production as showen in Figure 2B for the PB29 that has high number of bunch formation at three years

(A)

(B)

Figure 2. Plot of progeny PB29. (A) Plot setup for individual replicate for the initial year of planting (0 year after planting); (B) individual palm (3 years after planting)

Table 4. The preliminary comparison of FFB yield between PB29 and SC7 in drought area.

	Progeny	
Years of harvesting	PB29	SC7
First (2017)	12.42 (+20%)	10.28
Second (2018)	17.94 (+38%)	12.90

*Parentheses show the percentage increase compared to SC7 after planting. Generally, in the event of water scarcity, the formation of female inflorescence is reduced and replaced with formation of male inflorescence. However, for PB29, its' ability to produce high number fertile female inflorescence, indicates strong evidence that this progeny might have one of the potential drought tolerance traits. According to Corley et al. (2018), drought reduced oil palm yield through a vegetative part including the fruit bunch number, by changes in the ratio of female to male inflorescences. Meanwhile, for other progenies, they show reduction of bunch number by producing lower PI. Since water is the critical factor for optimum oil palm growth, deficiency will act as a signal to repress the female sex expression, while an increase in the production of male flowers coupled with slow growth leads to poor productivity (Cha-um et al., 2013).

Progenies that are tolerant to drought may have a better root formation system indicated by a good vegetative growth even under water deficit conditions and vice versa to the susceptible progenies. These was reported previously that tolerant oil palm genotype had higher Total Root Length (TRL), Total Root Surface Area (TRSA) and Potential Root Water Extraction Ratio (PRER) than susceptible genotypes based on half distances between roots, and the distance of water migration from soil to root (Cha-um et al., 2013; Murugesan et al., 2017). Palms fibrous root system is capable of observing water quicker and commonly found at irrigated soil (0.7 m in depth), while deep roots systems (1.1 m) are mainly developed by palms that grow in rain-fed areas (Cha-um et al., 2013).

Even when the plant was still in the early growth stage, the progeny PB29 had showed an impressive performance by producing FFB yield at 17.94 t/ha. Meanwhile, others reported that trial on dry area produced FFB yield at 16-18 t/ha for palm age 8-10 years old, with Angola, Tanzania, La Me and some Deli lines are promising population, with the best crosses being Angola × Tanzania and Angola × La Me, which had better appearances, higher water potentials at dawn and higher leaf specific weights (Suresh & Mathur, 2009). Bayona-Rodriguez & Romero (2019) reported that IRHO parent palm is an outstanding cultivar which is a good response to dry periods. Interestingly, in this study the Banting-FGV × Yangambi progeny is the most drought tolerant compared to La Me line (SC11) and IRHO (Bayona-Rodriguez & Romero, 2019). Different drought tolerant background reports might be due to genetic differences of cultivars that were able to reduce photosynthesis rates up to 25% to 40% during water deficit (Bayona-Rodriguez & Romero, 2019). Therefore, selecting a right parent palm with a drought tolerance trait is important to produce progeny with the right genes in response to water deficit conditions to minimize oil yield loss.

Drought periods has an effect on male and female inflorescence ratio and decreased in bunch number. Water deficit has a direct impact on FFB and oil yield, up to 20% reduction. The water problem for oil palms is the result of climate changes that reduce precipitation and increase drought seasons. Furthermore, it is difficult to utilize irrigation systems in large areas to avoid water deficit or to reduce sessional dry impacts because of economical, technical and agricultural limitations (Jazayeri et al., 2015).

5. Conclusions

Drought is a major constraint for oil palm plantation, and we are highly depending on rainfall in most of cultivation regions. In this preliminary study, we found a potential progeny from cross-pollination palm that has tolerance to drought without a yield depression.

As the oil palm cultivation expands into drought-prone regions, drought tolerant planting material is urgently needed. As a result from this study, we have identified some potential parents of progenies PB29, PB16 and FC5579 that appear to transmit drought tolerance to their offspring. These potential parents will also be valuable for commercial seed production and oil palm breeding programmes in the future.

These results also can be used for omics studies, to find the likely genes, pathways, processes and mechanisms involved in oil palm response to drought which will lead to molecular assisted selection plant breeding programs.

Conflict of interest

The authors declare no conflict of interest.

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Decontamination of pineapple (*Ananas comosus*) juice using ozone as a non-thermal sterilisation method

O.V. Mapalagama[1], P.N.R.J. Amunugoda[*2], K.K.D.S. Ranaweera[1]

[1]Department of Food Science & Technology, Faculty of Applied Sciences, University of Sri Jayewardenepura, Gangodawila, Nugegoda, Sri Lanka.
[2] Food Technology Section (FTS), Modern Research and Development Complex, Industrial Technology Institute (ITI), Halbarawa Gardens, Malabe, Sri Lanka.

* Corresponding author: dr.amunugodapnrj@yahoo.com

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Keywords

Ozone, Microbial quality, Colour

Ozone is a non-thermal preservation technology used for enhancing shelf life and the safety of food products. The main objective of this study was to evaluate the effect of ozone on microbial decontamination and some physicochemical characteristics (soluble solids content, pH, titratable acidity, and colour), bioactive compounds and total antioxidant activity of pineapple juice. Ozone treatments were applied to pineapple juice at 4 different exposure times; at 15 minutes, 30 minutes, 45 minutes, and 60 minutes at 25°C and the overall impact on microbial load were evaluated. The reduction of aerobic plate count was recorded as 1.99 log cycles, and the reduction of yeast and mould count was recorded as 1.92 log cycles after exposure to 60 minutes of ozone at 200mg/hr dose concentration. However, some quality parameters were significantly affected by ozone treatments. The most prominent changes were observed for colour and total phenolic content. Colour parameters including Chroma, Hue angle, and b* value has been significantly reduced through the ozone treatment, but the total phenolics content has been increased significantly in ozonized juices. In this context, and particularly for the pineapple beverage, ozone has been exploited due to its potential for inactivating spoilage microorganisms while being moderately effective in the overall quality retention of the products.

1. Introduction

The consumption of soft drinks, such as colas and flavoured sodas, is reducing globally as they have high sugar content, artificial colouring agents, sweeteners, and other harmful additives which can cause negative effects on the human body. Because of this, a higher number of consumers are shifting towards natural fruit juices (Ruanpeng *et al.*,2017). Fruit juice is an extract, or an extractable fluid content of cells or tissues made by mechanically squeezing or pressing out the natural liquid in ripe fruits. Fruit juices are rich in macronutrients and micronutrients. They also provide a rich source of nutraceutical compounds that can provide better immunity and various other health benefits such as the prevention of heart diseases, cancer, and diabetes (Abeysinghe *et al.*,2007).

The perishable nature of fruit juices poses significant challenges associated with the production and preservation of fruit juices. Unless the juice is consumed fresh, storage at chilling or freezing temperatures is the only alternative to protect the organoleptic properties of juice (Kaur & Kumar, 2019). Considering the extension of shelf life and preservation of fruit juice, the most widely adopted technology remains the conventional thermal processing which ensures prevention of microbiological deterioration, elimination of oxygen and prevention of enzymatic action. Thus, thermal inactivation maintains product safety. In thermal processing, heat is generated by a heating source and transferred into the product through conduction and convection mechanisms. This heat processing ensures the microbial safety of the food product (Petruzzi *et al.*,2017).

However, thermal processing may cause changes in bioactive compounds as well as organoleptic changes. Alternative non-thermal technologies have been studied to obtain ready-to-drink "fresh-like" juices with minimum nutritional, physicochemical, functional, or organoleptic changes (Esteve & Frigola, 2007). These emerging non-thermal technologies include high hydrostatic pressure, pulsed electric field, ozone processing, membrane filtration and ultraviolet light (Yildiz *et al.*,2019).

Among these non-thermal processing technologies, ozone processing is used in various processing systems today. In 2001, the US FDA approved ozone in the gaseous and aqueous phases (21CFR173.368) as an effective antimicrobial agent for foods (Khadre, Yousef & Kim, 2001). The food industry has started utilising ozone processing methods for pathogen inactivation. They have conducted research involving the application of ozone to preserve various fruit juices, such as apple cider, orange juice, strawberry juice, and apple juice (Patil *et al.*,2009).

Ozone is widely used in the food industry because it has many advantages over other treatments. Ozone is a triatomic allotrope of oxygen that decomposes rapidly to nontoxic oxygen, thereby leaving no harmful residues in food materials (Burleson, Murray, and Pollard, 1975). Ozone shares a higher oxidation potential of 2.07V; therefore, it is used as an effective antimicrobial agent (Fisher *et al.*,2000; Kim, Yousef & Dave, 1999). Due to its higher oxidation potential, it can destroy most microorganisms at relatively low concentrations. Ozone effects various cellular components like proteins, peptidoglycans in cell envelopes, enzymes, and nucleic acids in the cytoplasm of bacteria. When microbes get contacted with ozone, it initiates oxidation of the cell envelope, and that will cause cell lysis (Daş, Gürakan & Bayindirli, 2006; Khadre, Yousef & Kim, 2001).

Studies on the efficiency of ozone application in fruit juices have been done, mainly in apple and orange juices (Miller and Silva, 2013), focusing on quality and safety characteristics. Color, pH, soluble solids content, and phenolic compounds are the most studied characteristics for apple juices, while ascorbic acid is also often reported for orange juice. The majority of works reported significant colour alterations and ascorbic acid decay in ozonised juices (Patil *et al.*,2010; Tiwari, Muthukumarappan, O'Donnell, & Cullen, 2008; Torres *et al.*,2011), which was highly dependent on the fruit, treatment time and ozone concentration applied. The efficacy of ozone on bacteria inactivation has been mainly studied for Salmonella and Escherichia coli with observed reductions of up to 5 log-cycles (Patil *et al.*,2010; Patil *et al.*,2009; Williams, Sumner, & Golden, 2005).

However, there are some knowledge gaps concerning the effect of ozonation on the quality of tropical fruit juices. Therefore, the main objective of this work was to evaluate the efficacy of Ozone as a non-thermal sterilisation technique for pineapple juice (variety Mauritius) compared to thermal pasteurisation.

2. Materials and methods

2.1. Sample preparation

The matured pineapples purchased from the local market (Malabe, Sri Lanka) were cleaned by washing three times with potable water, with 100 ppm chlorine solution and again with potable water. The outer scales, eyes and inner core of pineapples were removed, and the fruit was cut into pieces. The pieces were blended using a domestic juice extractor, and the obtained juice was filtered through a clean muslin cloth. Then the filtered juice was mixed with water and food-grade sugar according to a formula of 18% filtered fruit juice, 73% water and 9% sugar and stored in a refrigerator at 4 ± 1°C until further analyses.

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2.2. Hot Filling / Pasteurisation

The prepared juice was heated in a water bath until the temperature reached 80oC and then it was maintained at 80oC for 15 minutes. The heated juice was then filled into sterile dark glass bottles and capped. Then the bottles were allowed to cool, labelled, and stored in the refrigerator (4°C).

2.3. Ozone treatment

Ozone treatment was performed according to the method described in Czekalski *et al.,*. (2016) with some modifications. Ozone gas was generated in a closed system using water ozoniser (Model No. 11022 Kent RO systems India) using a corona discharge method in a 500 ml conical flask (Figure 1). The fixed ozone output concentration at 200 mg/h was directly pumped into the juice through a food-grade silicone tube into the beaker and stirred using a magnetic stirrer (100 rpm) to ensure the ozone molecules were completely mixed with the sample. Treatment was provided at four different exposure times: 15 minutes, 30 minutes, 45 minutes and 60 minutes and treatment temperature were fixed at 25°C (Room Temperature). Untreated fruit juices (control = 0 minutes of ozone exposure time) and treated fruit juice were stored at 4 ± 1°C in sterile dark glass bottles to protect from light. All the described experiments were performed in triplicate, and all analyses were immediately performed after processing (within an hour).

2.4. Microbiological analysis

All beverage samples obtained as untreated, hot-filled / pasteurisation (which will be referred to as thermally processed, from here on), and ozone processed were tested for microbial safety by subjecting them to aerobic plate count test and yeast and mould count test (Keyser *et al.,*2008). For each ozone treatment time, 1mL of juice was removed, and aerobic bacteria were determined by pour plating the diluted samples onto Plate count agar. The plates were incubated at 30°C (Sanyo MIR-262) for 72 hours. Microbial counts were performed in triplicate and expressed as CFU/mL.

Yeast and mould were enumerated by spread plating the diluted samples onto the Dichloran Glycerol Media base. The plates were incubated at 25°C (Sanyo MIR-262) for 5 days. Microbial counts were performed in triplicate and expressed as CFU/mL.

2.5. Physicochemical analysis

2.5.1. Soluble solids content, pH, and titratable acidity

Soluble solids content (SSC), pH and titratable acidity (TA) of juice samples were directly analysed: pH was measured using a pH meter (EUTECH Instruments, PH510, pH/ mv/°C meter); SSC was measured with a Palette PR-32 digital refractometer (Atago, Tokyo, Japan) and was expressed as °Brix; titration was conducted with a 0.1M NaOH and TA was expressed as a

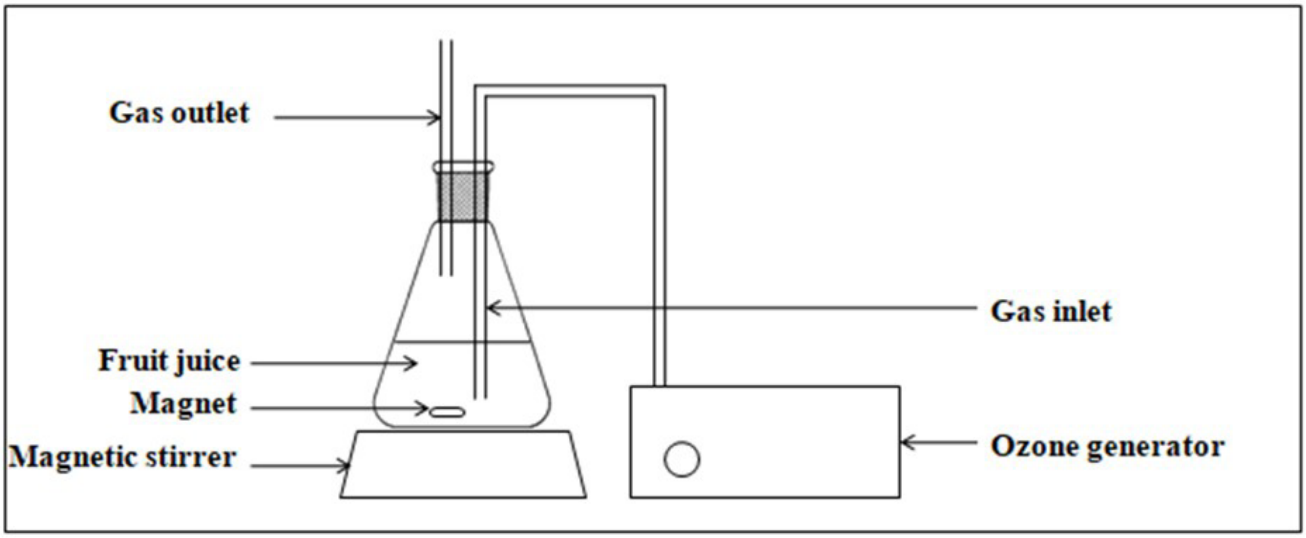

Figure 1. Schematic diagram of the ozone treatment system

percentage by mass of sample according to the following equation (1) (Sadler and Murphy, 2010).

$$\text{Titratable Acidity (\% by mass)} = \frac{6.404 \times V \times M}{m} \quad (1)$$

In the above equation, V is the Volume (in ml) of standard NaOH required for titration, M is the Molarity of the standard NaOH solution, and m is the Mass (in g) of the sample taken for the test.

2.5.2 Colour measurement

The colour coordinates (L*, a*, b*) of juice samples were measured using a Minolta CR-400 colourimeter (Konica-Minolta, Osaka, Japan). For each sample, three readings were carried out. Chroma (colour intensity) and hue angle (red at 0°, yellow at 90° green 150° and blue at 270°) (Hammond, 2016) were determined, according to the following equations:

$$\text{Hue Angle } (H^0) = \tan^{-1}(b^* / a^*) \quad (2)$$

$$\text{Chroma value} = \sqrt{(a*)^2 + (b*)^2} \quad (3)$$

2.5.3 Oxidation-reduction potential and active hydrogen score

The digital oxidation-reduction potential meter (EUTECH Instruments, Cyberscan pH110, pH/ mv/°C meter with RS232) was calibrated against standard solutions. The prepared juice samples were mixed well to homogenise, and the ORP values were measured using the calibrated ORP meter at room temperature. The active hydrogen score (rH) was calculated from the oxidation-reduction potential (ORP) and the pH of the juice, using the following formula (Holmes & Farley, 2008).

$$rH = ((ORP + 200) / 30) + (2 \times pH) \quad (4)$$

2.5.4 Viscosity

Rheological properties of pineapple juice were measured using ROTAVISC Rotational viscometer with No.2 spindle head. 200ml of each sample was placed in a glass beaker, and the spindle was set at 60rpm and 100rpm at 30 ± 2°C and the viscometer reading was taken (Jaramillo-Sánchez *et al.*,2018).

2.6 Bioactive compounds determination

2.6.1 Total phenolic content

The total phenolic content of juice samples was determined by the Folin-Ciocalteu reagent using 96-well microplates. 20µl from each juice sample was mixed with 110µl of Folin-Ciocalteu reagent and 70µl of 10% sodium carbonate solution. It was left for incubation at room temperature (25 ± 2 °C) for 30 minutes. The absorbance was read at 765nm, and Gallic acids with different concentrations were used as the standard antioxidant to construct the standard curve (Margraf *et al.*,2015).

2.6.2 (DPPH) 2, 2-Diphenyl-1-Picrylhydrazyl radical scavenging activity

Radical scavenging activity of the pineapple juices against stable 2,2-diphenyl1-picrylhydrazyl was determined by the method of Cuvelier and Berset, 1995. Briefly, 3 mg of DPPH and 50 mL of pure methanol were dissolved to get the stock solution. Then, it was stored at 20 ± 1°C until further use. Next, 2.5g of sample was mixed with 25 mL of 50% methanol and incubated for 30 min. The mixture was then centrifuged at 2,000 rpm for 5 min. Then, 2 mL of juice samples were vortexed before reaction with 2 mL of the DPPH-methanol solution at room temperature in the dark after 30 min. A UV spectrophotometer (Model UV-1700, Shimadzu, Japan) was then used to measure the absorbance at 517 nm. Standard ascorbic acid was used for the preparation of the standard solution series.

2.7 Statistical analysis

The statistical data analysis was performed for all experiments using ANOVA to test the significance of each variable (α = 0.05) and followed by a comparison performed using the Tukey test by the statistical software MINITAB 17. One way ANOVA was used to determine the effect of treatments on different juice parameters for each juice type.

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3. Results and Discussion

3.1 Microbial survival

According to the results shown in Figure 2, the microbial count was reduced significantly when ozone treatment time increased. Results showed in Table 4.2 shows a log reduction of 0.94, 1.36, 1.87 and 1.99 of Aerobic bacteria (APC) at 15 minutes, 30 minutes, 45 minutes, and 60 minutes exposure to ozone gas, respectively. The initial yeast and mould counts were decreased by 0.61, 0.96, 1.39 and 1.92 log cycles after exposing ozone gas for 15 minutes, 30 minutes, 45 minutes, and 60 minutes. No microbes were recorded in the thermally processed juice sample.

In the food industry, a minimum reduction of 2 log cycles is required to consider an agent as antimicrobial (Tiwari and Mason, 2012). Since the results obtained showed a reduction of around 2 log cycles at 60 minutes ozone treatment, it can be considered a promising non-thermal technology for preserving pineapple juice. Log survival of the microbial population at each ozone processing time shows a significant difference ($p < 0.05$).

The ozone microbicide action can be related to the damage of several cellular constituents, including proteins, unsaturated lipids and respiratory enzymes in cell membranes, peptidoglycans in cell envelopes, enzymes and nucleic acids in the cytoplasm, and proteins and peptidoglycan in spore coats and virus capsids (Khadre, Yousef, & Kim, 2001).

3.2 Physicochemical characterisation

Soluble solids content describes the balance of sugars and acids present in a matrix, which mainly impact juice flavour. As can be observed in Table 1, ozone-treated samples have shown no significant difference in soluble solids content when compared to untreated samples ($p > 0.05$). This agrees with most published results of ozone processed juices (Miller and Silva, 2013). However, thermally processed juice sample shows a significant increment in Total Soluble Solids (TSS) content (TSS=14.00 ± 0.10). The concentration of solids during the thermal processing will lead to a higher TSS content than other treatments (Maskan, 2006).

Titratable acidity and pH describe the acidic nature of the food materials, giving insights into food quality. Titratable acidity describes the effect of organic acids on the flavour of the food. Most food acids are par-

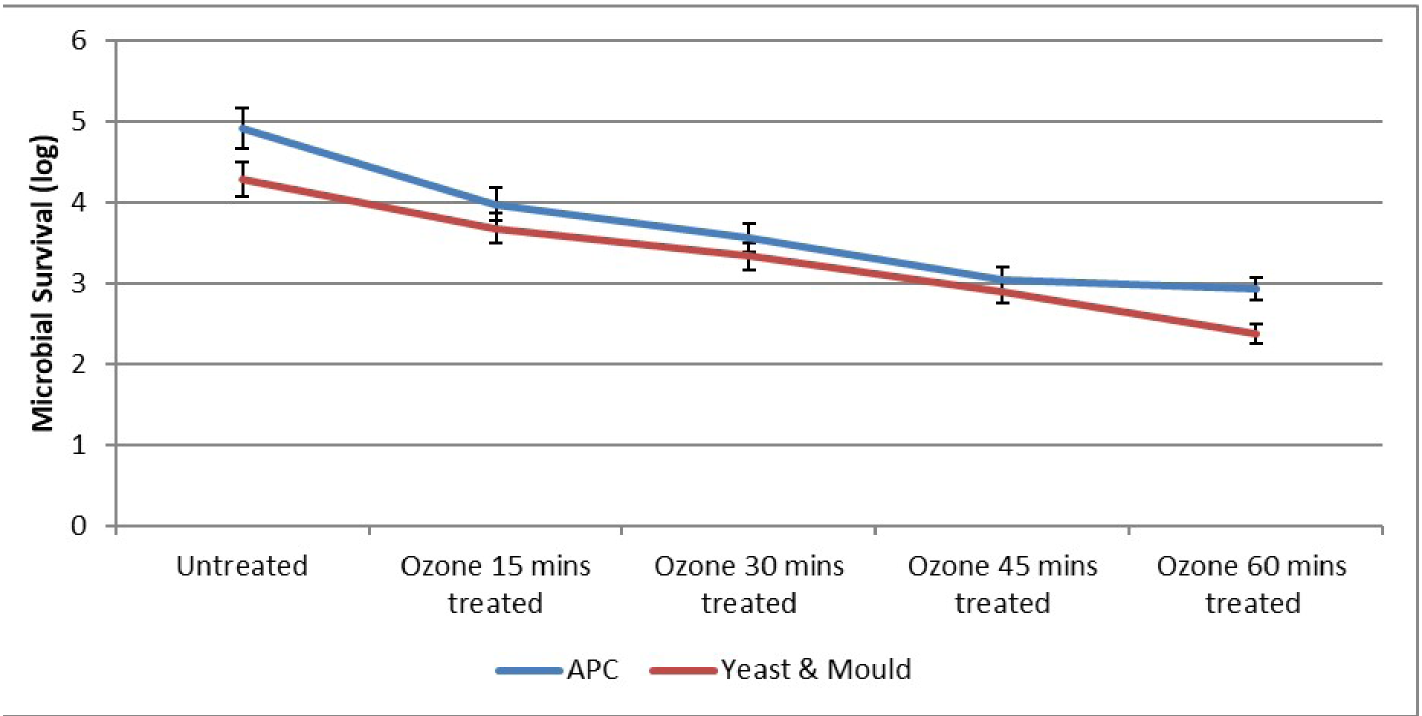

Figure 2. Microbial log survivals in Pineapple juice at different ozone processing times

tially ionised as they are weak in nature. Thus, some properties of foods are based on this ionised fraction of acids, whereas other properties are based on the total acid content. However, ozone processing did not significantly affect pH values and titratable acidity values of the juice. But thermal processing shows the highest mean value for titratable acidity (3.76 ± 0.005) due to the concentration of organic acids during the thermal processing. Therefore, it shows a significant difference in comparison to the untreated and ozone processed juices.

The colour of the untreated, thermally processed and ozone-treated juices are shown in Table 2. Here L, a* and b* values represent lightness, redness, and yellowness, respectively. All the colour parameters have shown a significant difference ($p < 0.05$). L* represents the lightness that has shown a significant increment over the ozone processing time. As shown in Table 3, the Chroma parameter showed a significant reduction in ozonised juices, indicating that ozone affected their colour intensity; however, no differences were observed between samples treated for 30 and 45 minutes. Related to hue angle, significant differences were obtained in untreated, thermally processed and ozone processed juices. The thermally processed juice had the most yellowness and vivid colour (b*=4.66 ± 0.09a and Chroma=4.67 ± 0.09).

Colour degradation of fruit juices due to ozone processing has also been reported for apple (Patil *et al.*,2010; Torres *et al.*,2011), grape (Tiwari *et al.*,2009a), orange (Tiwari *et al.*,2008), strawberry (Tiwari *et al.*,2009b), and tomato juices (Brijesh K. Tiwari *et al.*,2009). Different compounds in fruit juices are responsible for different colours. Changes in colour of the juice are associated with the degradation of colour pigments in particular juice (Tiwari *et al.*,2009).

Oxidation-reduction potential (ORP) indicates the dissolved oxygen concentration in water/liquid. As shown in Table 3, there is a significant difference ($p < 0.05$) in the ORP values between the untreated, thermally processed and ozone processed pineapple juices. 60 minutes ozone-treated juice shows the highest ORP mean value (275.33 ± 1.52), where thermally processed juice shows the lowest ORP mean value (249.67 ± 2.52). The reason for this is the elimination of dissolved oxygen during thermal processing.

Active Hydrogen score (rH) is the absolute indicator of the reductive potential of a substance which shows the number of ions in active hydrogen in solutions, of either organic or inorganic origin. This is a direct indicator of Total antioxidant content in the juice sample (Amorati and Valgimigli, 2015). However, the rH values calculated using the respective ORP values showed a significant difference between treatments

Table 1. TSS, pH and Titratable acidity values for different treatment conditions

Sample	Total Soluble Solids	pH	Titratable acidity
Untreated	11.07 ± 0.11^{b}	3.70 ± 0.005^{b}	1.36 ± 0.04^{b}
Hot Filled	14.00 ± 0.10^{a}	3.76 ± 0.005^{a}	1.81 ± 0.04^{a}
O_3 15 min treated	11.07 ± 0.06^{b}	3.70 ± 0.005^{b}	1.39 ± 0.05^{b}
O_3 30 min treated	11.03 ± 0.06^{b}	3.69 ± 0.005^{b}	1.36 ± 0.10^{b}
O_3 45 min treated	11.07 ± 0.12^{b}	3.69 ± 0.005^{b}	1.30 ± 0.00^{b}
O_3 60 min treated	11.00 ± 0.10^{b}	3.70 ± 0.005^{b}	1.41 ± 0.03^{b}

*Data presented as mean values for three replicates ± S.D. (n=3). Mean in the same column that does not share a letter significantly different at 5% significance level (Tukey HSD test).

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Table 2. Colour parameters of Pineapple juice under different treatment conditions

Sample	*L**	*a**	*b**	Chroma	Hue Angle
Untreated	14.59 ± 0.18[d]	0.24 ± 0.03[c]	3.55 ± 0.13[b]	3.56 ± 0.13[b]	86.03 ± 0.35[a]
Hot Filled	14.10 ± 0.13[e]	0.35 ± 0.05[b,c]	4.66 ± 0.09[a]	4.67 ± 0.09[a]	85.69 ± 0.71[a]
O_3 15 min treated	14.74 ± 0.17[c,d]	0.55 ± 0.05[a]	3.06 ± 0.05[c]	3.11 ± 0.04[c]	79.75 ± 0.06[b]
O_3 30 min treated	14.87 ± 0.02[b,c]	0.48 ± 0.03[a]	2.80 ± 0.06[d]	2.84 ± 0.06[d]	80.20 ± 0.55[b]
O_3 45 min treated	15.00 ± 0.05[b]	0.50 ± 0.03[a]	2.76 ± 0.01[d]	2.80 ± 0.01[d]	79.58 ± 0.64[b]
O_3 60 min treated	15.29 ± 0.03[a]	0.45 ± 0.03[a,b]	2.41 ± 0.04[e]	2.45 ± 0.03[e]	79.39 ± 0.85[b]

*Data presented as mean values for three replicates ± S.D. (n=3). Mean in the same column that does not share a letter significantly different at 5% significance level (Tukey HSD test).

Table 3. ORP and rH values for Pineapple juice under different treatments

Sample	ORP	Active H score
Untreated	267.67 ± 2.31[b]	22.99 ± 0.06[b]
Hot Filled	249.67 ± 2.52[c]	22.52 ± 0.08[c]
O_3 15 min treated	267.33 ± 1.52[b]	22.99 ± 0.06[b]
O_3 30 min treated	269.33 ± 0.57[b]	23.03 ± 0.01[b]
O_3 45 min treated	270.66 ± 0.57[b]	23.08 ± 0.03[b]
O_3 60 min treated	275.33 ± 1.52[a]	23.25 ± 0.06[a]

*Data presented as mean values for three replicates ± S.D. (n=3). Mean in the same column that does not share a letter significantly different at 5% significance level (Tukey HSD test).

($p < 0.05$). The highest score was reported in 60 minutes ozone-treated sample, implying that it contains the highest total antioxidant content. At 15 minutes, 30 minutes and 45 minutes, ozone-treated samples share no significant difference in rH score with the untreated sample.

Considering the viscosity of pineapple juice, there is a significant difference at 60 rpm and 100 rpm for the untreated, thermally processed and ozone-treated juice samples (Table 4). The thermally processed juice sample shows the highest mean viscosity value, 11.86

± 0.30 and 13.60 ± 0.10 at 60 rpm and 100 rpm, respectively. At 60 minutes, ozone processing viscosity decreased significantly, showing the least mean viscosity of all treatments.
Obtained results agree with the findings of prior research which reported a decrease in apparent viscosity in ozonised apple juice (1–4.8% w/w ozone) during 12 minutes of exposure (Torres *et al.,*2011). Similar results were obtained in the ozone processing of peach juice (Jaramillo-Sánchez *et al.,*2018).

Fruit juices exhibit two different phases as the pulp and the serum. The fruit pulp comprises fruit tissue cells, whereas the serum is a mixture of sugars, acids, salts, and soluble polysaccharides. Therefore, the rheology of fruit juices is defined by the interactions inside and between each phase. Because of its strong oxidising activity, ozone exposure has been reported to decrease the molecular weight of food polymers as pectins, resulting in a decrease in viscosity (Muthukumarappan *et al.,*. 2016).

3.3 Bioactive compounds and antioxidant activity

According to Table 5, total phenolic content in untreated and thermally processed juice samples have no significant difference ($p < 0.05$). Considering the ozone-treated samples, the highest polyphenolic content was recorded in 60 minutes ozone-treated sample, which is 866.67 ± 15.28 mg of gallic acid equivalents per 200ml of sample on a dry weight basis. Results showed that TPC significantly increased when exposure time increased.

This reaction to ozone treatment could be attributable to the activation of phenylalanine ammonia-lyase (PAL; EC 4.3.1.5). PAL is one of the key enzymes used in the synthesis of phenolic compounds in plant tissues. Recent researchers found that the activation of PAL in mango 'Haden' fruits were strongly correlated with the increase in the phenolic content of the fruits (González-Aguilar, Zavaleta-Gatica and Tiznado-Hernández, 2007). According to some research studies PAL can be stimulated by different stimulants rather than wounding (Camm and Towers, 1973). The increase in the phenolic contents of the juice might have also been caused by cell wall modification that occurred during ozone exposure; this modification may have increased the extractability and freed some of the conjugated phenolic compounds in the cell wall. Studies have suggested that the walls of guard and subsidiary cells of °3-treated spruce needles became de-lignified through the reaction with ozone (ozonolysis), which resulted in the accumulation of non-lignin phenolic compounds (Maier-Maercker and Koch, 1992).

DPPH radical scavenging activity of untreated thermally processed and ozone-treated samples show a significant difference ($p < 0.05$). According to Table 6, the highest mean value for DPPH radical scavenging activity was observed in the untreated sample. However, during ozonation DPPH radical scavenging activity decreased compared to the untreated sample. But there is no such pattern in the reduction of DPPH radical scavenging activity with ozone exposure time.

Table 4. Viscosity values for juice under different treatments

Sample	Viscosity at 60 rpm (cP)	Viscosity at 100 rpm (cP)
Untreated	10.10 ± 0.10^{b}	12.23 ± 0.15^{b}
Hot Filled	11.86 ± 0.30^{a}	13.60 ± 0.10^{a}
O_3 15 min treated	10.10 ± 0.10^{b}	12.20 ± 0.20^{b}
O_3 30 min treated	10.03 ± 0.15^{b}	12.13 ± 0.15^{b}
O_3 45 min treated	10.03 ± 0.20^{b}	12.10 ± 0.10^{b}
O_3 60 min treated	9.46 ± 0.15^{c}	11.60 ± 0.10^{c}

*Data presented as mean values for three replicates ± S.D. (n=3). Mean in the same column that does not share a letter significantly different at 5% significance level (Tukey HSD test).

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Table 5. Total Polyphenolic content of juices under different treatments

Sample	mg of Gallic acid equivalents/ ml of sample	mg of Gallic acid equivalents/ 200ml of Sample (1 Bottle)
Untreated	1.81 ± 0.05^{d}	363.33 ± 11.55^{d}
Hot Filled	1.65 ± 0.00^{d}	330.00 ± 00.00^{d}
O_3 15 min treated	2.58 ± 0.07^{c}	516.67 ± 15.28^{c}
O_3 30 min treated	3.15 ± 0.10^{b}	630.00 ± 20.00^{b}
O_3 45 min treated	4.18 ± 0.11^{a}	836.70 ± 23.10^{a}
O_3 60 min treated	4.33 ± 0.07^{a}	866.67 ± 15.28^{a}

*Data presented as mean values for three replicates ± S.D. (n=3). Mean in the same column that does not share a letter significantly different at 5% significance level (Tukey HSD test).

Table 6. DPPH radical scavenging activity of juices under different treatments

Sample	mg of β ascorbic acid equivalents/ml of sample	mg of ascorbic acid equivalents / 200ml of Sample (1 Bottle)
Untreated	0.04788 ± 0.00^{a}	9.576 ± 0.009^{a}
Hot Filled	0.04488 ± 0.00^{c}	8.976 ± 0.009^{c}
O_3 15 min treated	0.04552 ± 0.00^{b,c}	9.105 ± 0.019^{b,c}
O_3 30 min treated	0.04551 ± 0.00^{b,c}	9.102 ± 0.038^{b,c}
O_3 45 min treated	0.04611 ± 0.00^{b}	9.222 ± 0.039^{b}
O_3 60 min treated	0.04500 ± 0.00^{c}	9.000 ± 0.057^{c}

*Data presented as mean values for three replicates ± S.D. (n=3). Mean in the same column that does not share a letter significantly different at 5% significance level (Tukey HSD test).

Considering the results obtained in Total Polyphenolic content (Table 5), and DPPH radical scavenging activity (Table 6), there is some contradiction, as ozone treatment has induced the antioxidant content in TPC, wherein DPPH radical scavenging activity shows a reduction in antioxidant content after ozonation. One explanation is the auto-decomposition of ozone is accompanied by the production of numerous free radical species, such as hydroperoxyl (H2O•), hydroxyl (•OH), and superoxide (•O2−) radicals. Therefore, the by-products of ozone decomposition were scavenged by the phenolic compounds in the samples to different extents, which might have led to the reduction of DPPH radical scavenging activity of the samples after ozone exposure (Hoigné and Bader, 1983).

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4. Conclusion

It can be concluded that ozone can be a helpful process in low contaminated juices since a reduction of around 2 log cycles of aerobic bacteria and yeast and mould were obtained after 60min. However, ozone treatments significantly affected some of the quality characteristics analysed in the pineapple juice. The most prominent changes were observed for colour and antioxidant activity. Despite these negative impacts of ozone on the juice, the total phenolics content increased as the exposure time increased, with 68% of the variation. In conclusion, the effect of ozone on the nutritional and organoleptic quality of pineapple juice must be considered before adopting it as a preservation technique. Different ozone concentrations and exposing times should be tested, aiming at minimising overall quality losses.

Conflict of interest

The authors declare no conflict of interest

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Food Rescue and Donation in Socioenvironmental Policies on Tackling Food Loss and Waste: a Systematic Review

MÔNICA YOSHIZATO BIERWAGEN[1*], SYLMARA LOPES FRANCELINO GONÇALVES DIAS[1]

[1]School of Arts, Sciences and Humanities, University of São Paulo - USP, São Paulo, Brazil.

* Corresponding author: moyobi@usp.br

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In recent years, there has been an increasing concern among governments about Food Loss and Waste (FL&W), and, in this context, the Food Rescue and Donation (FR&D) has emerged in the socio-environmental policies scenario as a strategy for FL&W reduction. Even though FR&D has the potential to establish a "win-win" arrangement between the spheres of waste management and demands of food security, it still has been perceived as a less attractive alternative than forwarding the surplus food to the waste treatment systems. Thus, this paper aims to understand what the practice of FR&D consists of and identify its limits and possibilities for inclusion in socio-environmental policies. A systematic literature review was undertaken from January to April 2020 (Scopus database) and September 2021 (Web of Science database), focusing on scientific papers. Conducted under the PRISMA Statement recommendations, 42 articles were scrutinised. The results suggest most authors and studies on FR&D are from developed countries, although food insecurity is more often present in developing countries. Furthermore, a conceptual scan was carried out to explain what the practice of rescue is and define its object. It was concluded that, despite the apparent "win-win" solution, integrating FR&D and encompassing food security and solid waste management, the study unveiled contradictions that deserve further and deeper investigations on its effectiveness as a socio-environmental policies tool.

1. Introduction

In recent years, Food Loss and Waste (FL&W) has been an increasing concern to governments, and in this context, Food Rescue and Donation (FR&D) has emerged as a strategy for FL&W reduction. Even though FR&D has the potential to establish a "win-win" arrangement between waste management actions and the demands of food security (i.e., to ensure the decrease of hunger and malnutrition amongst socioeconomically vulnerable populations, as compromised by SDG 2 [1]), FR&D still has been a less attrac-

[1] Sustainable Development Goal 2. In 2015, the General Assembly of United Nations, by Resolution 70/1, adopted the 17 Sustainable Development Goals – SDGs and 169 targets as a part of the 2030 Agenda for Sustainable Development. The SDG 2 states Zero Hunger as a goal to be achieved by 2030.

tive alternative than disposing of the surplus food in the waste treatment systems (Aiello, Enea, & Muriana, 2015).

This is a puzzling situation because even though there is not an international consensus, the Food Waste Hierarchy from the US Environmental Protection Agency (US EPA) suggests food recovery for human purposes as preferable than waste treatment (EPA, [s.d.]). The "paradox of scarcity in abundance" (Rovati, 2015) highlights serious dysfunctions in modern food systems, which waste a significant quantity of food, despite the contingent of dependents on food donation systems being on the rise, even in developed economies. FR&D, in this scenario, can contribute to the immediate relief of food insecurity problems and the prevention of waste. However, once it is a strategy that faces only the consequences, but not the causes of FL&W, it has limitations that must be considered when designing and managing public policies.

Therefore, this study aims to understand what the practice of FR&D consists of and identify its limits and possibilities for inclusion in socio-environmental policies. For that, it will attempt to answer the following questions: What is FR&D, and how does it operate? To which extent may FR&D be embedded in socio-environmental policies, especially to promote integrated solutions for solid waste management, FL&W, and food insecurity?

A systematic literature review was carried out utilising the PRISMA Statement (Moher et al., 2009). Systematic reviews are beneficial, both theoretically and practically, once by collecting and organising data under a transparent and reproducible scientific process, biases are minimised, and thus greater security in information produced is achieved (Tranfield, Denyer, & Smart, 2003).

The literature review was planned and carried out according to the following steps: definition of procedures for collection and selection of papers (Section 2, "Materials and Methods"); identification and presentation of the main findings in the selected literature (Section 3, "Results"); and a critical and articulated analysis of the results (Section 4, "Discussion").

By having completed all these phases, it was possible to conclude that the concept of food rescue is primarily associated with the idea of preventing surplus food from becoming waste and being destined for the treatment system (Aiello, Enea, & Muriana, 2015; Bilska, Wrzosek, Kołozyn-Krajewska, & Krajewski, 2016; Busetti, 2019), and once it is suitable for human consumption, it should have the purpose of feeding people affected by food insecurity (De Pieri, Tallarico, Baglioni, Soler, & Ricciuti, 2017; Hecht & Neff, 2019; Mousa & Freeland-Graves, 2017; Reynolds, Piantadosi, & Boland, 2015; Vlaholias, Thompson, Every, & Dawson, 2015a).

Furthermore, considering the extent of integrating the FR&D into socio-environmental policies to fight FL&W, observed that the alleged complementarity of measures against food insecurity and prevention of solid waste as a "win-win" solution is more intuitive than real (Arcuri, 2019; Kinach, Parizeau, & Fraser, 2019; Warshawsky, 2016; Vlaholias, Thompson, Every, & Dawson, 2015b).

2. Materials and Methods

Following the PRISMA Statement recommendations, to select the most relevant scientific papers, a search on the Scopus database was carried out in 2020 from January to April, and on the Web of Science data base, in September 2021. Figure 1 shows the papers selection process according to the PRISMA Statement.

The following protocol shows a complete process of steps carried out[2]:

1. Starting with the Scopus database, a broad search with few search key terms was performed, enabling a first exploratory approach on the literature. In the "Identification" phase (letter "A" in Figure 1), 6,326 titles were found. By applying a filter with several terms that certainly would not be related to the proposed objective (letter "B" in Figure 1), 3,519 titles were excluded; thus, 2,807 papers were left.

2. In the "Screening" phase, based on previous readings on the topic, terms identified as usual in the literature about FR&D were used as criteria for further selecting works. Applying this criterion in the "search within results" field, a set of 1,627 titles was obtained (letter "C" in Figure 1). From this, 485 were excluded by repetition, then 1,142 papers were left (letter "D" in Figure 1).

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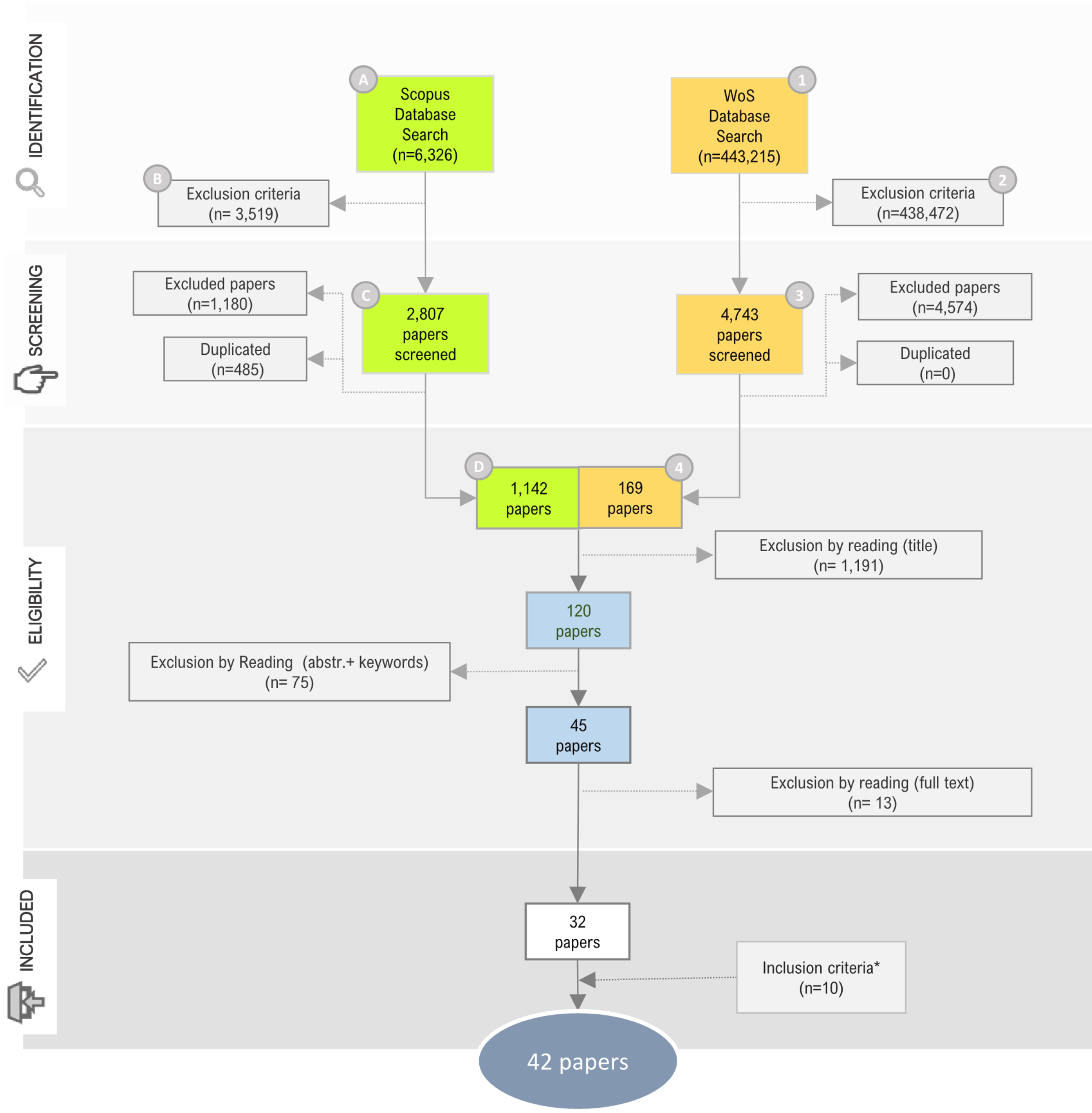

SEARCH CRITERIA:

A — **Key terms for selection (by title, abstract and keyword)**: food* and donat* or donor*

1 — **Key terms for selection (by title, abstract and keyword)**: food* and donat* or donor*

B — **Key terms for exclusion (by title, abstract and keyword)**: not blood* and not cell* and not transufsion* and not hiv and not hepatitis and not milk* and not breast* and not disaster* and not refug* and not diet*

2 — **Selection criteria**: document type (article, book chapter, conference paper, paper review) and WoS categories (food science technology, environmental sciences, nutrition dietetics, agronomy, ecology)

C — **Key terms for selection (by title)**: rescu* or bank* or recover* or secur* or surplus*

3 — **Key terms for selection (by title)**: food and donat* or (rescu* or waste* or loss* or recover* or surplus* or insecur* or secur* or safe*)

D — **Outcome of Screening Phase (Scopus):** 1,142 articles

4 — **Outcome of Screening Phase (WoS):** 169 articles

* Articles withdrawn based in exclusion criteria in latter phases, or not retrieved by the search, but previously known by the authors, both relevant for the study.

Figure 1. Papers selection process

3. An analogous procedure was performed within the Web of Science – WoS database search. The "Identification" phase started with a broad search that resulted in a set of 443,215 articles (number "1" in Figure 1). These articles were filtered by the search criteria provided by the WoS platform, using the document type field and the "WoS categories" field, which entailed the exclusion of 438,472 articles and 4,743 papers left (number "2" in Figure 1).

4. In the "Screening" phase, a Boolean search in the title field provided the exclusion of 4,574, thus remaining 169 papers (number "3" in Figure 1).

5. In the "Eligibility" phase, the papers left from Scopus and WoS were joined in one single list of 1,311 articles. A careful reading of the titles resulted in the exclusion of 1,191 papers. The 120 remaining papers were appraised by reading the abstracts [3], and 75 of them were withdrawn. The 45 remaining were then submitted to a full reading that excluded of 13 of them.

6. To the 32 articles sent to the "Inclusion" phase, 10 others were added [4], totaling 42 papers to the analysis.

3. Results

In order to consistently organise the findings from the set of studies of this review, an exploratory perspective was adopted, and the following aspects were analysed: (I) frequency of the main topics amongst the empirical studies; (II) co-occurrence of topics in the papers related to FR&D; (III) geographic location and origin of the study, considering the first author or research centre.

The number of empirical (experimental or observational) studies is significant. Amongst all 42 selected papers, 29 were empirical, and only 2 were systematic reviews. Analysing the set of 29 empirical studies it was possible to categorise them considering the main topic focused on: food loss (from production to distribution); food waste (from retail to final consumption); legislation and public policies; and food donation programs/food banks/food donation networks. The quantitative superiority of papers on food waste is significant compared to the studies on food loss. Considering the studies that evaluated losses in relation to the stage in the food chain, the number of articles on waste in the retail-consumption phase is approximately twice as large as that one dedicated to the production-distribution phase, as seen in Figure 2.

Such outcome partially confirms, as it has already been pointed out in previous studies, that in developed countries, the rates of food waste are higher than of food loss, whereas, in developing countries, this ratio is reversed: the rates of food loss are higher than food waste (Gustavsson, Cederberg, Sonesson, Otterdijk, & Meybeck, 2011; HLPE, 2014)[5] .

In this sense, by crossing the topics "food loss", "food waste", "food security" and "food safety"[6], it was found that most of the selected studies have focused on the association of food security and food waste (54.23%), and food security and food loss (42.38%), whereas there are very few studies addressing food safety and FL&W (Table 1). This gap deserves some attention, particularly considering that food donation often occurs near the end of shelf life (De Boeck, Jacxsens, Goubert, & Uyttendaele, 2017), and comprises perishable food (including time and temperature controlled) (Bierma, Jin, & Bazan, 2019; Koutsoumanis et al., 2018), situations that sanitary and safety issues become more worrisome.

Finally, it was observed that 12 publications had shown Italy as the country the object of research be-

[2] This is a second amplified version of the protocol, redesigned after the reviewers' comments.

[3] Criteria for excluding papers by reading the abstract: two sets of keywords were created with words related to food waste management (food loss, food waste, waste prevention, waste management, surplus food, loss of products, prevention, food recovery, wasteful, excess food, waste minimization, environment, landfill, reuse, sustainability, land use, methane production) and to food security and food safety (food security, food poverty, donation, redistribution, nutritious food, social purpose, food safety, hungry, people in need, good Samaritan, social exclusion, food charity, charity, charitable food, undernourished, food bank, food aid, food overproduction, legal liability, redistribution, food assistance). To be eligible, the abstract must comprise at least one word of each set, simultaneously.

[4] In the "Included" phase, 8 of them were papers excluded by applying the criteria performed in previous stages of the selection process (e.g.: a paper that would be excluded by reading the abstract), which has returned to the corpus for their relevance to the objectives of this research. Two of them were papers not retrieved by the search, but previously known by the authors and included for its relation to the topic.

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longs to, followed by the US (n=7), both corresponding to nearly half of all collected studies for this review. Likewise, a large number of articles have had their first authors associated with Italian (n=12) and American (n=6) research institutes (Figure 3).

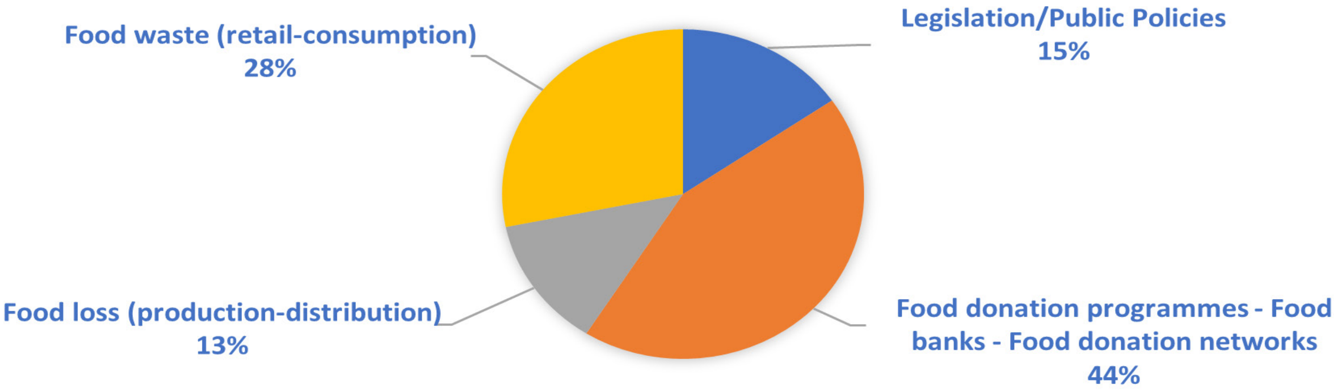


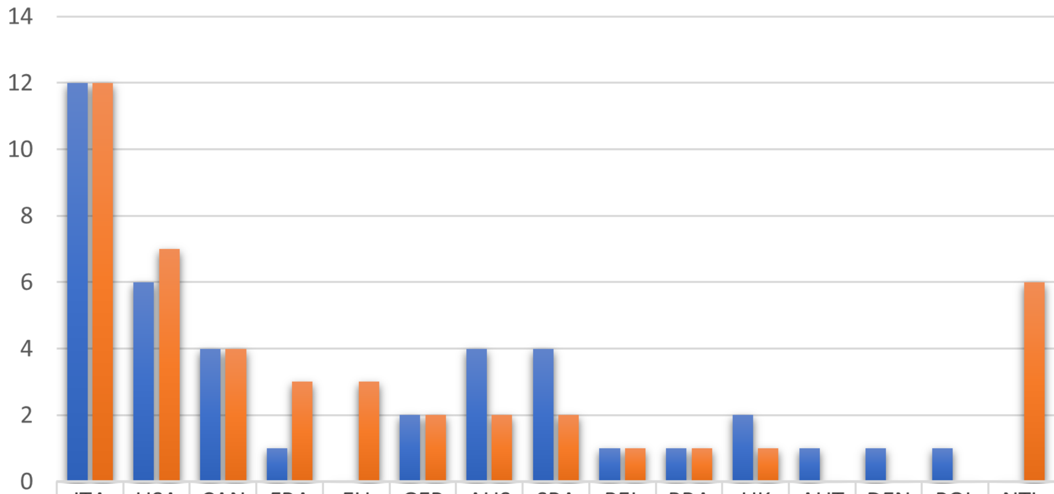
Figure 2. (I) Frequency of the main topics amongst the empirical studies

Table 1. (II) Co-occurrence of topics in the papers related to FR&D

Hunger Malnutrition \ Waste Management	FOOD LOSS	FOOD WASTE
FOOD SAFETY	0%	3.39%
FOOD SECURITY	42.38%	54.23%

[5] Brazil is an exception to the rule, as it has large food losses in the production phases, as well as a significant volume of food waste, especially among consumers (Porpino, Parente, & Wansink, 2015).

[6] Food safety regards procedures to cautioning the risk of foodborne illnesses, and in this sense, it may be considered part of food security. Nonetheless, in some FR&D papers food safety is focused as an independent topic (Bierma, Jin, & Bazan, 2019; De Boeck, Jacxsens, Goubert, & Uyttendaele, 2017; Koutsoumanis et al., 2018; Milicevic et al., 2016), so it was considered useful to count them separately. Food loss/food waste is also a widely used dichotomy in the literature to address the decrease in quantity or quality of food from post harvesting up to storage, and from retailing up to consumption, respectively.



	ITA	USA	CAN	FRA	EU	GER	AUS	SPA	BEL	BRA	UK	AUT	DEN	POL	NTL
1st. author	12	6	4	1	0	2	4	4	1	1	2	1	1	1	0
country (research object)	12	7	4	3	3	2	2	2	1	1	1	0	0	0	6

NOTE: FRA (France), ITA (Italy), USA (United States), CAN (Canada), UK (United Kingdom), AUT (Austria), BEL (Belgium), SPA (Spain), AUS (Australia), BRA (Brazil), GER (Germany), DEN (Denmark), POL (Poland), EU (European Union) and NTL (no territorial link)

Figure 3. (III) Origin of the first author and country of research

Regarding the country that the research object belongs to, there is almost a complete absence of approaches comprising the reality of developing countries;in the group of 29 articles, there was only one study about Brazil (Henz & Porpino, 2017). This disproportion is also observed when considering the first authors' institutes (Figure 3).

4. Discussion

The combination of measures to tackle food insecurity as well as to fight FL&W is intuitively assigned to a "win-win" situation: food, which would become waste and would be forwarded to the landfill due to dysfunctions in the food system, could be rehabilitated to fulfill its original function, i.e., human consumption. Despite that, FR&D has been a less-used alternative compared to the surplus food forwarded to the waste treatment systems (Aiello et al., 2015). This situation demands a better understanding of alternatives that ensure the most effectiveness of FR&D.

An aspect that must be highlighted refers to identified gaps in the literature: the lack of studies to measure the profitability of food recovery (Aiello, Enea, & Muriana, 2015; Albizzati, Tonini, Chammard, & Astrup, 2019; Reynolds, Piantadosi, & Boland, 2015), the cost of waste (Garrone, Melacini, & Perego, 2014; Phillips, Hoenigman, Higbee, & Reed, 2013), tax benefits (Garrone, Melacini, & Perego, 2014), and the environmental taxes of the rescue (Albizzati, Tonini, Chammard, & Astrup, 2019).

Authors also point out that there is a lack of studies on improving the efficiency of FR&D programs (Lee, Sönmez, Gómez, & Fan, 2017) and their impacts on food poverty, food insecurity, or hunger (Bazerghi, McKay, & Dunn, 2016; Phillips, Hoenigman, Higbee, & Reed, 2013).

Regarding methodological issues, there are voids in the scientific literature assessing and comparing the effectiveness of different models of food rescue (Hecht & Neff, 2019) and collecting data on food waste (Mousa & Freeland-Graves, 2017; Warshawsky, 2016). Also, there is a scarcity of studies that link food safety to local donation networks, or to the role of local health workers (Bierma, Jin, & Bazan, 2019).
Although such gaps deserve attention and provide an interesting range of possibilities for studies and re-

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search to deepen the knowledge on FR&D, it is noteworthy that such voids do not hamper the authors from pointing out advantages and showing critical aspects of the FR&D, which may help to understand why sending surplus food to the treatment system is still the most common option.

4.1. Food rescue and rescued food: conceptual framework

One of the aspects that stands out in the selected studies refers to the terminology used to refer to both the activity (food rescue) and its object (the rescued food), as well as the meanings attributed to such terms. Accordingly, besides "food rescue" (Hecht & Neff, 2019; Reynolds, Piantadosi, & Boland, 2015), the studies have expressions such as "food rescue nutrition" (Mousa & Freeland-Graves, 2017),"food redistribution" (Albizzati, Tonini, Chammard, & Astrup, 2019; Vlaholias, Thompson, Every, & Dawson, 2015a) and "food recovery" (P.L. González-Torre & Coque, 2016).

The literature also records the expressions like "rescuable food" (Hecht & Neff, 2019) and "surplus food" (Albizzati, Tonini, Chammard, & Astrup, 2019; Alexander & Smaje, 2008; Garrone, Melacini, & Perego, 2014; Sert, Garrone, Melacini, & Perego, 2015) to name what is subjected to the rescue. In a broader sense, surplus food can also comprise, in addition to "edible food", which means food of good quality and safe to be consumed, the "inedible food", which addresses parts culturally not recognised as "food", such as skin, stems, seeds, leaves (Hecht & Neff, 2019).

Although Hecht and Neff (2019), Reynolds, Piantadosi, & Boland (2015), and Vlaholias, Thompson, Every, & Dawson (2015a) use the term "food recovery" as synonymous with "food rescue," it is noteworthy that the term "recovery" is not used to re-establish a situation or a previous state: utilisation always occurs before the food becomes waste. In this context, the "wastage" is surplus food not used to feed people (Garrone, Melacini, & Perego, 2014) and it is identified by expressions such as "food loss" (Aiello, Enea, & Muriana, 2015; De Boeck, Jacxsens, Goubert, & Uyttendaele, 2017); ;); "food waste" (Albizzati, Tonini, Chammard, & Astrup, 2019; De Boeck, Jacxsens, Goubert, & Uyttendaele, 2017); Foti, Sturiale, & Timpanaro, 2018; Garrone, Melacini, & Perego, 2014; P. L. González-Torre & Coque, 2016; Kinach, Parizeau, & Fraser, 2019); "food loss and waste " (Kinach, Parizeau, & Fraser, 2019); "food wastage" (De Boeck, Jacxsens, Goubert, & Uyttendaele, 2017) and "wasted food" (Foti, Sturiale, & Timpanaro, 2018).

4.2. Rescue of food in the integration of policies to tackle waste and promote food security: limits and possibilities

As FR&D is recognised as a strategy that helps both raise the quality of life of those who have inefficient access to food and improve waste management systems efficiency, it´s not free from criticism and disagreements.

The reactions, ranging from "apoplectic" to "enthusiastic" (McIntyre, Patterson, Anderson, & Mah, 2017), are based on several motivations and grounds: highlighting the paradox of coexistence of food insecurity and waste, FR&D has been recognised as an ethical (Thyberg & Tonjes, 2016) or a morally acceptable solution (Lee, Sönmez, Gómez, & Fan, 2017; Rovati, 2015; Sakaguchi, Pak & Potts 2018; Sert Garrone, Melacini, & Perego, 2018; Tarasuk & Eakin, 2003).

However, from a political approach, Mura, Castiglioni, Borrelli, Ferrari, & Diamantini (2019) have problematised food donation from the concept of "food justice" - as an impossibility for low-income people to access high quality and healthy food. These authors emphasise the risk of worsening inequalities within the food system, and it might be aggravated in case of disregarding both food security and food safety issues. Gómez Garrido, Carbonero Gamundí, & Viladrich (2019), in turn, have analysed the core of "grassroots food banks," and have considered it as a counterpoint to the philanthropic feature of "conventional" food banks. According to the authors, by stimulating new forms of interpersonal collaboration, grassroots food banks may enable advances in a social and political emancipatory agenda, reinforcing claims for justice and protection of rights and against the typical assistance of donations, thus introducing solidarity in the social and political field.

From an economic perspective, Mousa & Freeland-Graves (2017), and Sert, Garrone, Melacini, & Perego (2018) say that the FR&D has been a low-cost alternative to feed people while avoiding the production of waste, while Arcuri (2019) and Vlaholias, Thompson, Every, & Dawson (2015b) refer to a conciliatory feature as a "win-win" solution, by allowing benefits for those in need as well as for donors.

Kinach, Parizeau, & Fraser (2019) and McIntyre, Patterson, Anderson, & Mah (2017) note limitations for FR&D as a strategy to fight food insecurity and improve waste management.On the one hand, regarding the stigma of recovered food as "food that would go to the garbage," and on the other, due to its limitations to accomplish rights, it cannot fully guarantee the human right to adequate food.

Nonetheless, despite the enticing idea to solve two significant issues (food insecurity and waste management) [7], it is necessary to understand the possibilities of conciliation, considering the conflicts of interest and the incompatibility of specific goals. Although FR&D has limitations, it´s not a useless strategy, so it must be viewed as a possibility of integrating such actions to fight waste and thus playing a complementary role within a more extensive set of policy measures.

4. 3. FR&D: far beyond charity

The first food bank in the world was created in 1960 in the United States [8], and from that time to the present day, FR&D has been intensified, become complex, spread around the world, and there is no doubt about its contribution to reducing food insecurity and food waste (De Pieri, Tallarico, Baglioni, Soler, & Ricciuti, 2017).

More recently, the shifting of the role of FR&D in developed countries - primarily influenced by the "Great Recession of 2008" (Arcuri, 2019; Gómez Garrido, Carbonero Gamundí & Viladrich, 2019), highlights the increasing dependency of people in food poverty of food banks, thus becoming a permanent source of feeding for them (Bazerghi, McKay, & Dunn, 2016; De Pieri, Tallarico, Baglioni, Soler, & Ricciuti, 2017; Rovati, 2015).

The ever-increasing dependency on these food sources has long-term implications, both because it is unable to fully provide the nutritional needs of its users (Mourad, 2016; Reynolds, Piantadosi, & Boland, 2015), and for creating a "welfare system" that eventually prevents them from achieving food security Kinach, Parizeau, & Fraser, 2019; Mura, Castiglioni, Borrelli, Ferrari, & Diamantini, 2019; Vlaholias, Thompson, Every, & Dawson, 2015b).

In addition, despite FR&D alleviating food necessities of the neediest populations, it ends up distancing them from the governments' attention and responsibility for ensuring food for all (Compagnucci, Cavicchi, Spigarelli, & Natali, 2018; P. González-Torre et al., 2017).

Lorenz (2012) points out that the charitable donations of food, especially in affluent societies, has an ambivalent feature: both because in this context there is more waste than hungry people and because, by creating alternative routes to market and institutions, there is a reinforcement rather than overcoming social exclusion, since it addresses the consequences rather than the causes of poverty.

Furthermore, as food banks depend on voluntary donations, there is an aggravation to quantity and to quality of food that will be donated: in the quantitative aspect, as observed by Tarasuk & Eakin (2003) and Adams, Christopher; Tabacchi (1997), to remain competitive in the market, as long as the efficiency of donor operations increases, there is a tendency of decreasing the number of donations.

In addition, food banks must distribute all food they collect, regardless of its nutritional value, as they are restrained to donor availability (Tarasuk & Eakin, 2005), and unpredictability, either on the supply (Bazerghi, McKay, & Dunn, 2016), or on the demand side (Lee, Sönmez, Gómez, & Fan, 2017). This situation

[7] In France, Law n. 138/2016, the "Law against food waste" (*Loi relative à la lutte contre le gaspillage alimentaire*), is the first legal initiative in Europe to tackle food waste by prohibiting supermarkets (of over 400 square metres) of disposing surplus food in the waste treatment systems and obliging them to donate it to charitable organisations (Foti et al., 2018; Baglioni, De Pieri, & Tallarico, 2017)

[8] John Von Hengel, a retired businessman who worked in the 1960s as a volunteer in a soup kitchen in Phoenix, Arizona, founded the first food bank in the United States. He noticed that while the soup kitchen did not have enough food to serve to the people in need, restaurants and supermarkets in the surroundings were throwing away good food. He started to collect the wasted food from these companies and donate it to feed the needy (Schneider, 2013).

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makes it difficult for action plans to promote a healthy diet. Regarding food healthiness, Tarasuk & Eakin (2005) observe that the way food banks work and organise the distribution of industrialized products, albeit they seem to create an alleged "win-win" situation among the hungry and corporations, they end up delivering not-sold food from industry, undermining nutritional requirements of people in need.

Moreover, as observed by Tarasuk & Eakin (2003) and followed by P González-Torre, Lozano, & Adenso-Díaz (2017), another important consequence of the way food banks work is that they make the needs of the beneficiaries invisible. Once the hunger problem seems to be managed, the financial support for this population becomes unnecessary, and both the community and the government make fewer efforts to overcome food poverty leading to more inequality and a greater reliance on assistance from food banks.

4.4 Study limitations

It is essential to highlight that, according to the criteria defined in the methodology herein, there was no intention to restrict the research to FR&D in developed countries. However, considering the selected studies, there is a set of empirical studies limited to developed countries, so it is not clear if this has occurred randomly or if recent publications have privileged studies of FR&D in developed countries. It is also necessary to consider that the search criteria were undertaken in English, which may be a limiting factor in selecting non-English speaking countries. Thus, more focused studies will confirm whether there are, in fact, few studies addressing the situation of developing countries.

5. Conclusions

The FR&D is a strategy that has not yet achieved practical results in line with the expectations attributed to it, even though it has gained visibility in recent years, mainly due to the potential to face two major challenges of contemporary public policies (fighting food insecurity and adequate waste management)
This is partially due to the complexity involved in FR&D operations: logistical, institutional, cultural, and legal challenges, which impose limits and possibilities for its integration into the public policies field. Nevertheless, there is a shift in the historical process of charity assistance by adding to its objective's benefits to the environment.

The interests identified apparently would be a "win-win" situation, in which all stakeholders have benefits: the poor, because they get food; companies, because they dispose of the waste and get rid of the disposal costs; the environment, because the deviation of suitable food from the treatment route. Nonethless a careful evaluation points out that it might not reach the expected outcome.

Thus, aiming to critically problematise the FR&D, first, it is concluded that there is a need for further studies mainly regarding the situation of developing countries, allowing a research agenda focused on these countries. Second, the integration of FR&D into public policies addressing the waste management and food insecurity issues is helpful; however, it is not a solution neither for the environmental impacts of FL&W nor the problems of hunger and malnutrition. On the contrary, the literature points out the misappropriation of FR&D operations by a market rationale, which might reinforce the same means and reasons for the emergence of losses and food waste in the food chain.

Conflict of Interest

The authors declare no conflict of interest. Besides, the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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Antioxidant activity of a mixture between water-soluble tempeh extract and whey powder that has undergone a Maillard reaction

AZIS BOING SITANGGANG[1], NISRINA ZULFA FIRDAUSI[1] AND SLAMET BUDIJANTO[1*]

[1]Department of Food Science and Technology, IPB University, Bogor, Indonesia

* Corresponding author: slametbu@apps.ipb.ac.id

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The high amino acid content in over fermented tempeh and lactose in whey powder can be combined to perform a Maillard reaction. This strategy can be used to produce functional food products. Like the Maillard reaction products,, melanoidins have been reported to have high antioxidant capacities and own a preferred flavor. The study's general objective was to obtain the optimal processing conditions in a mixture of water-soluble tempeh extract and whey powder with the highest antioxidant capacity. The research was carried out in three stages: (i) selecting the best whey powder concentration, (ii) initial reaction pH, and (iii) obtaining the kinetic parameters of the Maillard reaction with respect to the antioxidant activity of the reacted mixture. The mixture ratio between water-soluble tempeh extract and whey powder of 5.0 % (w/v), reacted at 100 °C and pH 5.0 for 90 min, could increase the antioxidant activity from 67.91 ± 2.62 % to 89.89 ± 0.17 %. That concludes as the optimal conditions for the Maillard reaction between water-soluble tempeh extract and whey powder with an IC50 of 47.82 mg/mL.

1. Introduction

Fermented soybean, otherwise known as tempeh, is a traditional food from Indonesia, which is widely known by the general public. Rhizopus sp. is the dominant microorganism for fermenting soybean during tempeh production (Fibri and Frøst 2019). The macromolecules in soybeans are converted into simpler forms by the extracellular enzymes produced during tempeh's fermentation process. Specifically, the fermentation increases the levels of free amino acids (AA), ammonia, and low molecular weight peptides due to protein degradation by proteases (Aryanta 2000; Liu and Pan 2011). There is no significant difference observed in protein content between soybean and tempeh. However, the dissolved protein content in tempeh increased due to the activity of the proteases (Astuti *et al*., 2000). Tempeh contains 20-55 % db protein (Kiers *et al*., 2000; Babji *et al*., 2010; Bavia *et al*., 2012; Rusdah *et al*., 2017). Low molecular weight peptides in tempeh have the potential to be bioactive compounds, such as antioxidative, antimicrobial, antihypertensive, antidiabetic, anticancer, and anti-tumor compounds (Amadou *et al*., 2017; Sanjukta and

Rai 2016; Tamam *et al*., 2019). Apart from peptides, other bioactive compounds found in tempeh are flavonoids, especially isoflavones that act as antioxidants (Kuligowski *et al*., 2017). The optimal soybean fermentation for producing tempeh is about two to three days. Tempeh is considered to be over fermented when the fermentation is longer than this period. The traditional tempeh sellers normally use the over fermented tempeh as part of animal feeds or possibly discharge it directly to the environment. Considering the high amount of protein in over fermented tempeh, simple aqueous extraction can be used to recover water-soluble protein, which is useful for other purposes (Arianingrum *et al*., 2007).

Whey is a by-product produced from the manufacture of cheese and casein in the dairy industry. About 85% of the total milk used was wasted as a whey by-product from dairy manufacture (Panesar *et al*., 2012). Whey can be purified, pasteurized, and dried to produce whey powder. Whey powder contains about 11 - 14.5% protein, 63 - 75% lactose, and 1 - 1.5% fat (Kadam *et al*., 2018). The composition of the whey product varies depending on the milk source, production method, cheese type, and industry specifications. Lactose is a disaccharide in milk and is the main component in solid whey (Chegini and Taheri 2013). High lactose content in whey powder can be used as a source of sugar to form flavor resulting from caramelization. As a by-product of the cheese-making industry, the utilization of whey processed into food products is still quite low (less than 50%), the rest is disposed of as waste into the environment (Alonso *et al*., 2011; Sitanggang *et al*., 2016). Whey will be beneficial for the cheese industry because it reduces the cost of waste processing and valorizes the by-products.

The Maillard reaction or non-enzymatic browning reaction is a complex reaction between compounds with a carbonyl group (reducing sugars) and compounds containing amine groups (amino acids, peptides, or proteins) (Chawla *et al*., 2007; Hwang *et al*., 2011).

The Maillard reaction is divided into three stages the: initial stage, the intermediate stage, and the final stage (Hodge 1953). The final stage of the Maillard reaction produces a brown pigment known as melanoidins (Liu *et al*., 2008) that have been reported to have functional properties as antioxidants (Wagner *et al*., 2002). Melanoidin compounds, which are polymers with large molecular weights, have fairly large antioxidant capacities. That is due to functional structures in melanoidins such as enol and enamiol, which can act as antioxidants. The corresponding hydroxyl groups can reduce the oxidation process by reducing metals, chelating metals, and scavenging free radicals (Fardiaz *et al*., 2006).

Based on the existing characteristics, the combination of water-soluble protein obtained from over fermented tempeh and whey powder can produce functional food products. The high amino acid (AA) content in water-soluble tempeh extract and lactose in whey powder can be used as substrates to form a derivative food product with a high antioxidant capacity and preferred flavor through the Maillard reaction. This can be used to valorize the by-products and a basis for developing functional food products in the form of beverages. Hence, this study aimed to optimize the Maillard reaction conditions between water-soluble tempeh extract and whey powder.

2. Materials and Methods

2.1. Materials

The over fermented tempeh (4-d fermentation) was obtained from the Indonesian Tempe Cooperative (KOPTI), Bogor, West Java, Indonesia. Whey powder was a gift from Fonterra, Indonesia. Sodium hydroxide (NaOH), methanol (CH_3OH), 2,2-diphenyl-1-picrylhydrazyl (DPPH), ascorbic acid were purchased from Merck KGaA (Darmstadt, Germany). All other chemicals were analytical grade.

2.2. Preparation of water-soluble tempeh extract

4-d tempeh was cut (3.0 x 0.5 x 0.5 cm) and placed in a cabinet dryer at 70 oC for seven hours. Size reduction was performed by pin disc mill, and the tempeh flour was sieved using 80 Tyler mesh. The preparation of water-soluble tempeh extract was conducted by dispersing tempeh flour in distilled water with a tempeh flour-to-water ratio of 1:5 (w/w). The extraction was performed at 30 oC, with an agitation of 500 rpm for two hours. The slurry was centrifuged at 3000 rpm for 15 min, and the supernatant was recovered (Christianti 2019).

2.3. Maillard reaction

The preparation of the reacting volume was carried

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out on a 100-mL basis. The controls consisted of water-soluble tempeh extract (C), whey powder at a concentration of 2.0, 5.0, and 10.0 % (w/v). The unreacted mixtures, such as C11, C12, and C13, were the mixtures of water-soluble tempeh extract with whey powder at a concentration of 2.0, 5.0, and 10.0 % (w/v), respectively. The selection of the best concentration of whey powder was made by reacting the mixtures at 100 ° C, initial pH 7 for one hour, and shaking at 200 rpm. The liquid fraction of the sample was obtained by centrifugation at 300 rpm, followed by 0.45 μm membrane filtration. The recovered liquid was analyzed for antioxidant activity, browning intensity, and lightness value. The reacted mixtures between water-soluble tempeh extract with whey powder at a concentration of 2.0, 5.0, and 10.0 % (w/v) were denoted as R11, R12, and R13.

The best concentration of whey powder was used to investigate the best initial reaction pH. The six pH values were pH 3.0, 4.0, 5.0, 6.0,7.0, and 8.0. The procedures to recover reacted mixture for the analyses were the same as mentioned above.

The kinetics of the Maillard reaction based on the changes in antioxidant capacity was carried out by reacting the mixture of water-soluble tempeh with whey powder at the best whey powder concentration and initial reaction pH. The Maillard reaction was performed at four levels of temperature (70, 80, 90, 100 oC) for three hours, in which the sampling was conducted every 30 min. The rate constant k, a parameter that indicates how fast a reaction can proceed in each heating temperature, was evaluated following zeroth (0th), first (1^{st}), and second (2^{nd}) reaction order, as following (eqs. (1), (2), and (3)):

0^{th} reaction order: $$A = A_0 + kt \quad (1)$$

1^{st} reaction order: $$\ln A = \ln A_0 + kt \quad (2)$$

2^{nd} reaction order: $$\frac{1}{A} = \frac{1}{A_0} - kt \quad (3)$$

where A_0 and A: initial and final antioxidant capacity (mg AEAC/L), respectively, and *t*: reaction time (h). The selection of the appropriate reaction order for describing the rate constant was based on the coefficient of determination (R^2) obtained from the linear equations above. The calculation of the energy activation for the Maillard reaction was following Arrhenius equation (eq. 4):

$$\ln k = \ln k_0 - \frac{Ea}{R}\frac{1}{T} \quad (4)$$

where k_0: a constant, *Ea*: activation energy (kJ/mol), R: gas constant (8.31x 10^{-3} kJ/K mol) and *T*: temperature (°K).

2.4. Antioxidant activity

The antioxidant capacity was analyzed according to Brand-William *et al.* (1995) and Sitanggang *et al.* (2020a) with modifications. A total of 1.0 mL sample was added with 3.0 mL of DPPH solution in methanol (120 μM) in a screw-cap test tube. The mixture was vortexed for 15 s and incubated in a dark room for 30 min. The absorbance was monitored at a wavelength of 515 nm with a UV-VIS spectrophotometer (Thermo Scientific Genesys-150, USA). 1.0 mL of distilled water was used to substitute the sample for the control. The antioxidant activity was expressed as percent inhibition or radical scavenging activity (eq. 5):

$$Inhibition(\%) = \frac{(A_c - A_s)}{Ac} x100\% \quad (5)$$

where A_c and A_s: absorbance of the control and sample, respectively (-). The ascorbic acid standard curve was used to calculate antioxidant capacity. The capacity was expressed as ascorbic acid equivalent antioxidant capacity (mg AEAC/L). In addition to this, the concentration of the recovered supernatant (mg/mL) from the best reacting conditions, which can inhibit the oxidation process by 50 %, or the half-maximal inhibitory concentration (IC_{50}), was also measured.

2.5. Browning intensity

The browning intensity (A_{420}) of the sample was evaluated by measuring the absorbance of the recovered supernatant using a UV-VIS spectrophotometer (Thermo Scientific Genesys-150, USA) at 420 nm (Karseno *et al.*, 2018).

2.6. Lightness value

Colour analysis was performed by chromameter (Minolta CR 300, Osaka, Japan) in triplicate. The values of

L (lightness value), *a* (red-green), and *b* (yellow-blue) for each sample were measured. Prior to measurement, the instrument was calibrated with a standard white plate (CIE L *: +97.30, CIE a *: –0.09, CIE b *: +1.94).

2.7. Amino acid analysis

The analysis of amino acids was performed by a commercial laboratory, PT. Saraswanti Indo Genetech (18-5-17/MU SMM-SIG, UPLC), where the method has also been reported elsewhere (Sitanggang *et al.*, 2020b).

2.8. Statistical analysis

Each data point presented was an average of three replicates with a standard deviation. The analysis of variance (ANOVA) was performed using SPSS software (IBM, USA). One-Way ANOVA was used select the best concentration of whey powder and initial reaction pH. Two-way ANOVA was used in a completely randomized factorial design for choosing the best combination between reaction time and temperature. For both analyses, a confidence level of 95% was considered.

3. Results and Discussion

Selecting optimal whey powder concentration

As seen in Figure 1a, water-soluble tempeh extract and whey powder at different concentrations (2.0, 5.0, and 10.0 %) exhibited antioxidative properties. The water-soluble tempeh extract could inhibit free radicals with a percentage of 54.59 ± 2.95 %. The ability of water-soluble tempeh flour to inhibit free radicals has been reported in a range of 30 to 40 % (Puteri *et al.*, 2017). The higher inhibition value within this study was due to a higher tempeh flour-to-water ratio compared to that of Puteri *et al.* (2017). The high antioxidant activity in tempeh is due to the presence of flavone derivatives and low molecular weight peptides that are produced during fermentation (Chang *et al.*, 2009). In addition, water-soluble tempeh extract had the highest browning intensity corresponding to the lowest lightness value (Figure 1b, 1c, and 1d). Whey powder also shows the antioxidant property, and the increase in concentration is proportional to the increases in the antioxidant activity and the browning intensity (Figure 1a and 1b). Whey powder contains antioxidant compounds such as lactoferrin and lactoperoxidase (Bylund 2013). It can be considered a natural antioxidant (Ashous *et al.*, 2013), thus, used as an ingredient for producing functional foods.

Water-soluble tempeh extract can be used as a source of amino groups, while whey powder contains reducing sugars. The use of heat onto the mixture between water-soluble tempeh extract and whey powder can facilitate the Maillard reaction. The Maillard reaction is a typical non-enzymatic browning, a reaction between the carbonyl group of the reducing sugar and the amino group from amino acids or proteins, which forms the final compound, melanoidin. The reaction between the polar fraction of water-soluble tempeh extract and whey powder is homogeneous and produces water-soluble Maillard reaction products that exhibit antioxidant activity.

After the heating process (where the Maillard reaction took place), there was an increase in antioxidant activity and browning intensity of the mixture at whey powder of 2.0 and 5.0 % (w/v) (Figure 2a and 2b). The increase in antioxidant activity reached saturation as the inhibitions of the free radicals were relatively similar between mixtures at 5.0 and 10.0 % (w/v) whey powder. The application of heat (100 oC for one hour) could degrade the antioxidative isoflavones, such as genistein and daidzein (Ungar *et al.*, 2003; Kuligowski *et al.*, 2017). Herein, the enhancement of antioxidant activity for the reacted mixtures at 2.0 and 5.0 % (w/v) whey powder might be attributed to the formation of melanoidins. As a consequence, the brown colour was developed, followed by the reduction of lightness value (Figure 2c and 2d). The antioxidant activity of the reacted mixture at a whey powder of 10.0 % (w/v) was lower than that of the unreacted mixture despite having a higher browning intensity. A significant increase in total solid for the reacted mixture with 10.0 % (w/v) whey powder might require a higher heat content to establish a completed Maillard reaction. Besides having a Maillard reaction, the formation of brown colour in the reacted mixture with 10.0 % (w/v) whey powder could also be due to caramelization. According to Ajandouz *et al.* (2008), caramelization, a reaction where the sugars are heated at high temperatures, especially at the alkaline pH range, also contributes

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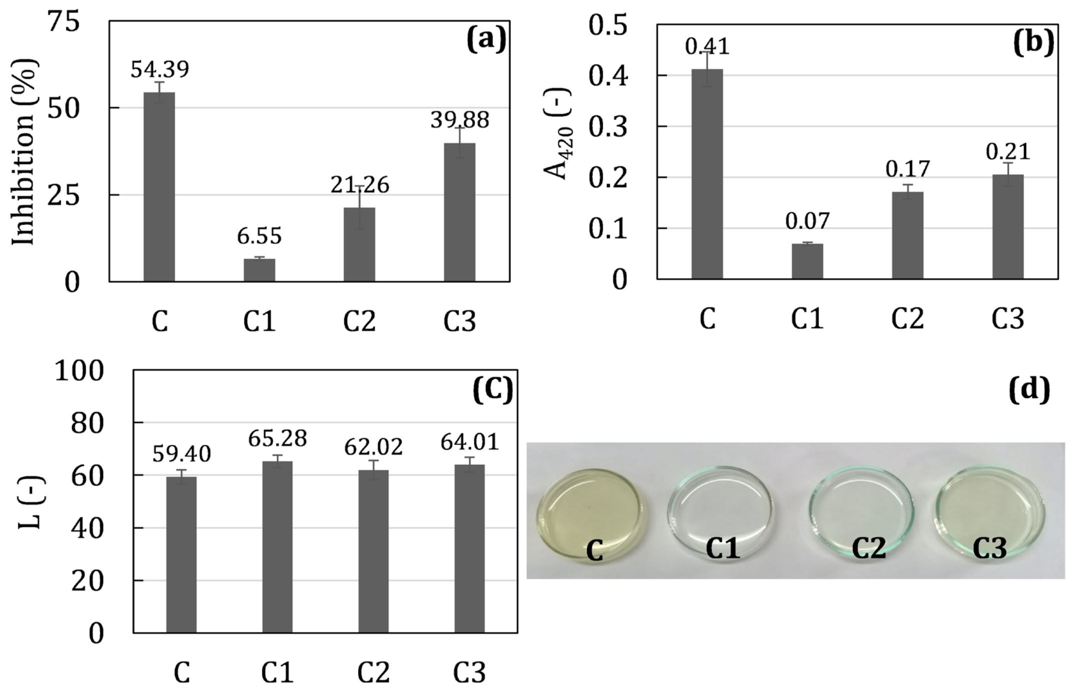


Figure 1. The antioxidant activity (a), browning intensity A_{420} (b), lightness value *L* (c), and the appearance (d) of water-soluble tempeh extract and whey powder control (C = water-soluble tempeh extract , C1, C2 and C3 = whey powder at 2.0, 5.0, and 10.0 % (w/v)).

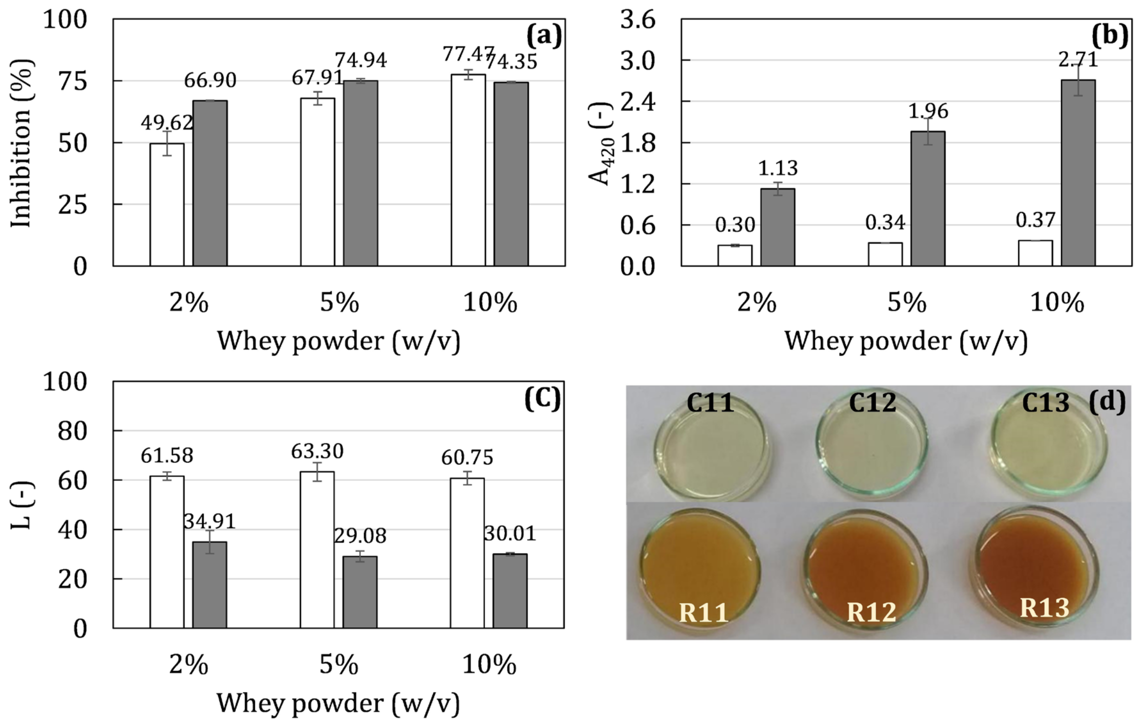


Figure 2. The antioxidant activity (a), browning intensity A_{420} (b), lightness value *L* (c), and the appearance (d) of a mixture between water-soluble tempeh extract and whey powder. White and grey bars represent unreacted and reacted mixtures, respectively; C11, C12, and C13 were unreacted mixtures between water-soluble tempeh extract and 2.0, 5.0, and 10.0 % (w/v) whey powder, respectively, whereas R11, R12, and R13 were the corresponding reacted mixtures (after the heating process).

to the overall non-enzymatic browning reaction. The antioxidant activity of the reacted mixture with 5.0 % (w/v) whey powder was significantly different compared with 2.0 % (w/v) whey powder. However, this value was not significantly different from that of reacted mixture with 10 % (w/v) whey powder, at a 95 % confidence level. In this study, whey powder at 5.0 % (w/v) was selected as the optimal concentration as the source of reducing sugars.

Selecting initial reaction pH

The initial pH of the mixture is a substantial reacting condition for a successful Maillard reaction. Melanoidin is formed at acidic or alkaline conditions due to the degradation of the Amadori compounds, followed by other chemical reactions such as dehydration, cyclization, and condensation. Within this study, six levels of mixture pH were utilized, namely pH 3.0, 4.0, 5.0, 6.0, 7.0, and 8.0. As shown in Figure 3a, reacted mixture at pH 5.0 obtained the highest antioxidant activity with a value of 89.31 ± 0.15 %. The initial pH impacts the overall Maillard reaction as there was a significant difference in antioxidant activity amongst treatments.

The initial pH of the reaction affects the solubility of proteins, peptides, and amino acids contained in the water-soluble tempeh extract. The solubility of proteins at a pH around the isoelectric point (pI) will decrease due to increased protein interactions (positively and negatively charged protein molecules). Water-soluble tempeh flour contains a high level of essential amino acids, such as leucine and lysine (Cahyani 2020). Lysine is alkaline and has an isoelectric point around pH 9.74 (Nagai and Carta 2004; Zeng *et al.*, 2011). Higher protein solubility in tempeh extract, especially at pH 5.0, caused a higher possibility for more amino acids and proteins to react with reducing sugars during the Maillard reaction. Lysine itself has a considerable influence on the Maillard reaction. Kwak and Lim (2004) reported that lysine is the most reactive amino acid to facilitate the Maillard reaction with various types of sugar compared to 11 other amino acids (aspartate, glutamate, alanine, leucine, isoleucine, valine, proline, serine, cysteine, phenylalanine, and arginine). The high lysine reactivity is due to two amine groups, namely α-amino and ε-amino. The acidic conditions (lower pH values) can also function as a catalyst for the hydrolysis of the glycosidic bonds in lactose. As monosaccharides, both glucose and galactose have higher reducing power than lactose. Herein, reducing lactose at acidic conditions is preferable for the Maillard reaction.

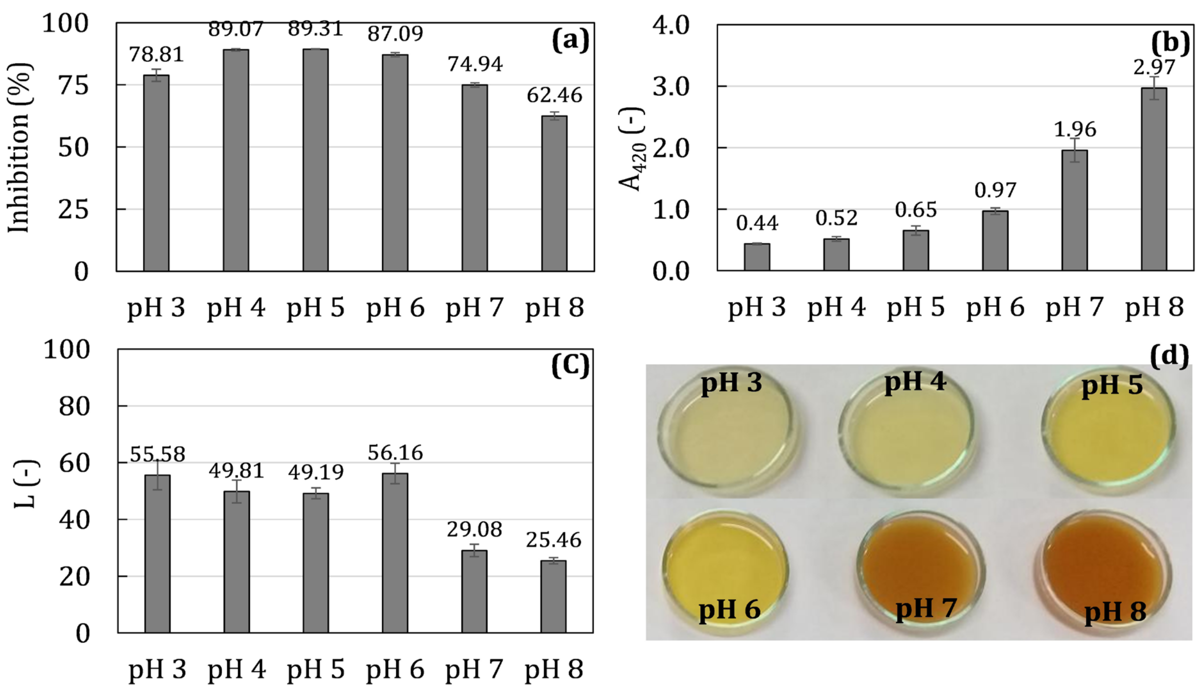


Figure 3. The antioxidant activity (a), browning intensity A_{420} (b), lightness value L (c), and the appearance (d) of reacted mixtures between water-soluble tempeh extract and whey powder at different initial pH values.

The increases in browning intensity fitted relatively well with the reductions of lightness value (Figure 3b and 3c). However, the increases in browning intensity did not correspond well with the levels of antioxidant activity amongst treatments (Figure 3a and 3b). In this study, the caramelization reaction also contributed to the brown color in the reacted mixtures, especially at high temperatures and high pH values (Ajandouz *et al.*, 2008). In alkaline conditions, the formation of Schiff base compounds was enhanced, thus, facilitating a higher rate of the Maillard reaction. Both caramelization and Maillard reactions simultaneously occurred (Wang *et al.*, 2013). Martins *et al.* (2000) reported that the formation of hydroxymethylfurfural (HMF) or furfural compounds from Amadori rearrangement is preferred at low pH values (pH< 7.0), whilethe formation of reduction compounds and fission compounds, such as acetyl, diacetyl, and pyruvaldehyde, are preferred at high pH values (pH> 7.0). Within this study, the antioxidant activity of the reacted mixture at pH 5.0 was not significantly different from that of pH 4.0. However, it was substantially different from pH 3.0, 6.0, 7.0, and 8.0, at a 95% confidence level. It concludes that pH 5.0 was the optimal initial pH for the Maillard reaction between water-soluble extract and 5.0 % (w/v) whey powder concentration.

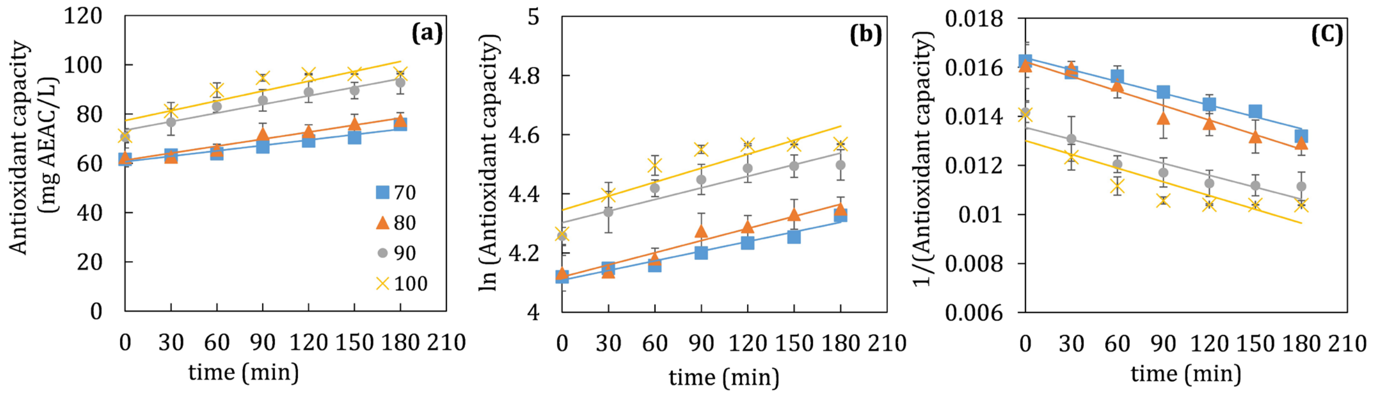


Figure 4. Kinetics of Maillard reaction following zeroth order (a), first-order (b), and second-order (c) of reaction

Table 1. Governing equations and coefficients of determination of the Maillard reactions at different heating temperatures.

Reaction order	Reaction temp. (°C)	Governing equation	Coef. Determination (R^2)
0th order	70	0.0736x + 60.63	0.9427
	80	0.0949x + 61.297	0.9517
	90	0.1163x + 73.408	0.9333
	100	0.1335x + 77.336	0.7907
1st Order	70	0.0011x + 4.1083	0.9554
	80	0.0014x + 4.1188	0.9496
	90	0.0013x + 4.3023	0.8664
	100	0.0016x + 4.3451	0.7711
2nd order	70	-2E-05x + 0.0164	0.9659
	80	-2E-05x + 0.0162	0.9467
	90	-2E-05x + 0.0135	0.8489
	100	-2E-05x + 0.013	0.7498

Kinetics of maillard reaction based on antioxidant activity changes

The kinetics of the Maillard reaction was performed based on the changes in antioxidant capacity over a certain period. From Figure 4 (a-c) and Table 1, the highest coefficients of determination were obtained by following the zeroth order of the reaction. Reaction order with zero means the magnitude of the reaction rate constant is not affected by the initial concentration of the reactants, and the reaction rate constant increases with the increase in temperature. By employing eq. (4), a correlation between 1/T and ln k was obtained, $y = -2552.7x + 4.8552$ (Figure 5). The calculated activation energy Ea was 21.22 kJ/mol K.

This indicates that the minimum energy required to produce compounds exhibiting antioxidant activity was 21.22 kJ/mol K. The reported activation energy of the Maillard reaction ranges from 10-160 kJ/mol (Finot *et al.*, 1990). Ayranci and Dalgic (1990) reported the activation energies of the Maillard reaction of glucose-lysine and lactose-lysine were 153.1 and 162.5 kJ/mol K, respectively. Furthermore, the activation energy of the Maillard reaction between xylose and lysine with ultrasonic assistance was 55.59 kJ/mol K (Yu *et al.*, 2012).

3.4 Selecting the reaction time and temperature

There was a significant interaction between the reacting temperature and time at a confidence level of 95%. In general, the antioxidant capacity of the reacted mixture at 100 °C in each sampling plan was relatively higher than that at other temperatures. At 100 °C, the antioxidant capacity of the reacted mixture at 180 min of reaction was significantly different from 0, 30, and 60 min. However, this value was not significantly different from 90, 120, and 150 min of reaction. Therefore, the best time and temperature for the Maillard reaction between water-soluble tempeh extract and whey powder were 90 min and 100 °C, respectively. By this, the obtained antioxidant capacity was 94.64 ± 1.30 mg AEAC/L.

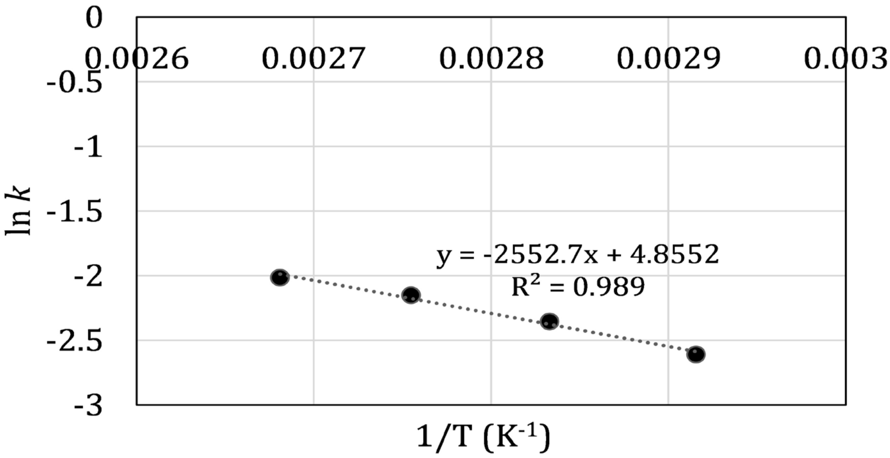
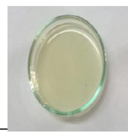


Figure 5. Correlation between 1/T and ln k.

Table 2. Comparison between the unreacted mixture and the optimal reacted mixture.

Mixture	Inhibition (%)	Browning intensity A_{420}	Lightness value L (-)	Appearance
Unreacted	67.91 ± 2.62	0.33 ± 0.003	63.30 ± 3.71	
After reaction (pH 5.0, T = 100 °C, t = 90 min)	89.89 ± 0.17	0.90 ± 0.081	48.28 ± 4.23	

The half-maximal inhibitory concentration (IC50) and amino acid composition

The Maillard reaction was considered successful to increase the antioxidant activity of the reacted mixture. This was indicated by the higher antioxidant activity of the optimal reacted mixture as compared to that of the unreacted mixture (Table 2). Additionally, the browning intensity of the reacted mixture was enhanced whilst having a lower lightness value than that of the unreacted mixture. The antioxidant activity of the reacted mixture with optimal reacting conditions was 89.89 ± 0.17 % with an IC_{50} value of 47.82 mg/mL. The calculated IC_{50} value for ascorbic acid (vitamin C) was 0,05 mg/mL. A lower IC50 value indicates stronger antioxidant activity (Salazar-Aranda *et al*., 2011). Hereby, the optimal reacted mixture of water-soluble tempeh extract and whey powder had a weaker antioxidant activity compared to that of ascorbic acid. On the other hand, the obtained antioxidant capacity as mentioned previously was 94.64 ± 1.30 mg AEAC/L. The reported antioxidant capacities of commercial ready-to-drink orange juices and nectars in Brazil were reported between 70-400 and 110-480 mg AEAC/L, respectively (Stella *et al*., 2011). Therefore, the antioxidant capacity of the optimal reacted mixture in this study was comparable to that of Stella *et al*. (2011). Moreover, the dominating amino acids for both water-soluble tempeh extract and optimal reacted mixture were glutamic acid, aspartate, lysine, and leucine (Figure 6). Several amino acids have been reported to have antioxidant properties, such as proline, histidine, tyrosine, cysteine, valine, leucine, phenylalanine, and tryptophan (Sitanggang *et al*., 2020b). These amino acids were also obtained in the optimal reacted mixture.

4. Conclusion

The optimal Maillard reaction conditions between water-soluble tempeh extract and whey powder were 5.0 % (w/v) whey powder, initial reaction pH of 5.0, a reaction time of 90 min, and a temperature of 100 °C. The Maillard reaction was performed with 21.22 kJ/mol activation energy. The Maillard reaction was considered successful as it could enhance the antioxidant activity from 67.91 ± 2.62 % to 89.89 ± 0.17 %. Additionally, the browning intensity of the reacted mixture was enhanced, thus having a lower lightness value than that of the unreacted mixture. The IC50 value of the product was 47.82 mg/mL with an antioxidant capacity of 94.64 ± 1.30 mg AEAC/L. This val-

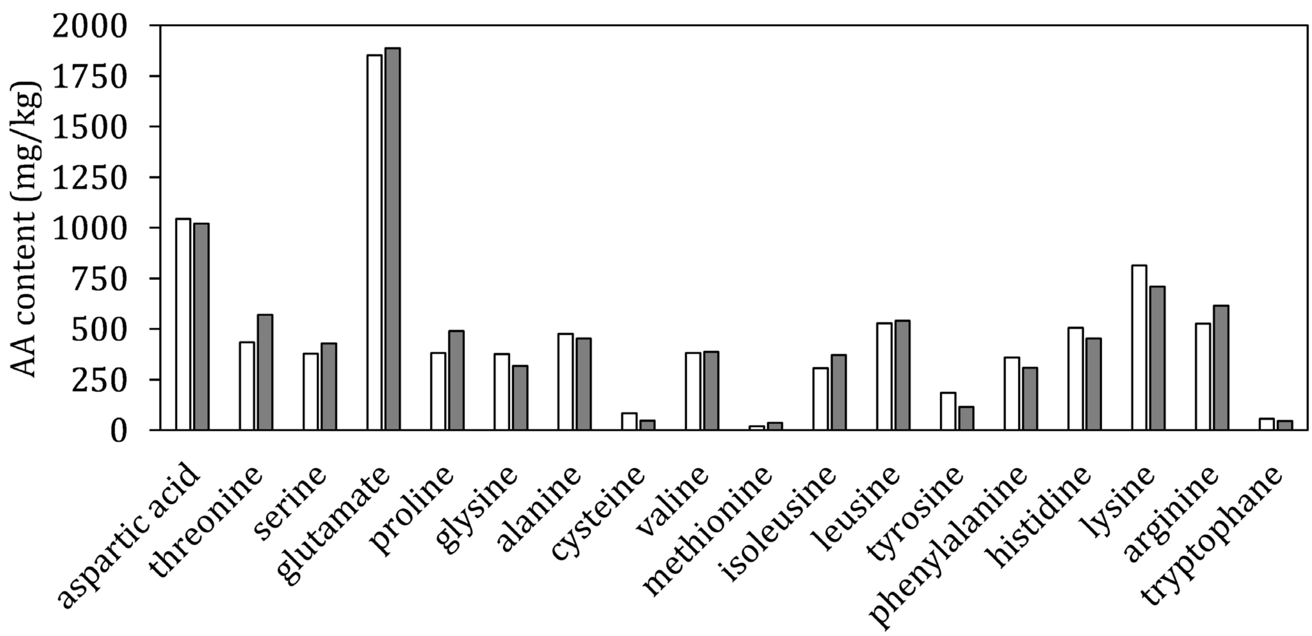


Figure 6. Amino acid (AA) composition of water-soluble tempeh extract (white bar) and optimal reacted mixture (grey bar).

ue was comparable with the antioxidant capacities of commercial ready-to-drink orange juices and nectars reported elsewhere.

Conflict of interest

The authors declare no conflict of interest.

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Research Paper

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Influencing factors of adopting solar irrigation technology and its impact on farmers' livelihood. A case study in Bangladesh

Md. Jaber Rana[1,*], M Kamruzzaman[2], Md. Moinul Hosain Oliver[3], Kaynath Akhi[2]

[1] Department of Agricultural Economics, Khulna Agricultural University, Khulna-9100, Bangladesh.
[2] Department of Agricultural Economics, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazi pur-1706, Bangladesh
[3] Department of Agricultural Engineering, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh.

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Keywords

Probit Model; farmers' livelihood; Composite Capital; Solar powered irrigation system.

Access to irrigation is considered critical for agricultural growth in Bangladesh. Solar-powered irrigation system (SPIS) has emerged as a promising technology for sustainable irrigation practice in the country. This study reports the factors that affect the adoption process of SPIS in the farming community. It also explores the impact of SPIS projects on the livelihood status of the farmers. In this regard, 140 farmers were directly interviewed from the Meherpur district of Bangladesh. Random sampling techniques were followed, and probit model analysis was conducted to identify the socio-economic factors that affect the adoption process. Capital and composite livelihood indices were prepared to examine the impact of SPIS projects on farmers' livelihood status. The result shows that education and extension services had a statistically positive effect on adoption. By contrast, access to credit, farm size, and off-farm income had a significantly negative impact on the adoption process. The result also shows that farmers using solar-powered irrigation technology had a better livelihood index in different indicators, i.e., human, social, natural, and technical capital, than diesel-powered irrigation system users.

1. Introduction

Irrigation is recognized as a measure that can enhance multiple cropping practices and improve yield (FAO, 2011). The agricultural success stories of Bangladesh have also been credited to the irrigation facilities developed countrywide (United Nations, 2015). There are nearly 1.61 million irrigation pumps currently active in the country (MOA, 2021). Among them, 83% of the pumps are operated by diesel engines. In order to keep them running, a supply chain of diesel fuel has been developed in the rural areas. However, the problem is that the fuel is heavily subsidised (Ahmed, 2010) by the Government of Bangladesh to keep the food production cost low. From this perspective, replacing diesel-powered pumps with solar-powered electric pumps seems more justified. Moreover, diesel-powered irrigation pumps emit large quantities of greenhouse gas. A recent study by Rana et al. (2020) showed that replacing half of the diesel pumps with solar pumps can reduce Bangladesh's carbon footprint by one million tons per year.

Bangladesh started deploying full-fledged solar-powered irrigation system (SPIS) projects in 2009. It is estimated that replacing all diesel water pumps with SPIS will generate 10,000 megawatts of solar energy (Halder et al., 2015). Bangladesh has since laid out a lavish plan to implement solar-powered irrigation systems which is expected to play an important role in Bangladesh's present and future energy mix. Solar-powered projects are mainly overseen by Infrastructure Development Company Limited (IDCOL), a government-owned company. IDCOL works with different non-government organizations and local private enterprises to implement SPIS. In addition, they also provide training on modern crop production practices regularly. Training is provided to those farmers who are eager to adopt new technology in irrigation (IDCOL, 2015). In recent years, the adoption of SPIS in Bangladesh has been growing but slowly, with a total installed capacity of 48.13 MW (SREDA, 2021).

The adoption of new agricultural technology like SPIS is a complex endeavour. The adoption process is thought to be mainly profitability related issues (Davies, 1979). The World Bank (2015) reported that SPIS has indeed reduced the irrigation costs in Bangladesh. Similar results have also been reported by Zakaullah et al. (2021), Kelley et al. (2010), and Khan et al. (2013), who found SPIS to be profitable for at least 5 years. From this perspective, the adoption of SPIS should have been easy. However, the slow growth of SPIS in Bangladesh has raised questions about what factors are affecting the process. It has long been argued that technology adoption decisions are based on heterogeneous factors such as human capital, farm size, information about technology, cost, risk, benefit, etc. Other factors like farm size (Akudugu et al., 2012), gender (Atibioke et al., 2012), higher education (Uddin et al., 2014), longer experience (Ainembabazi and Mugisha, 2014), age of farmers (Mendola, 2007), larger incomer earner (Mottaleb et al., 2016), neighbor's adoption, and land ownership (Hailu et al., 2014) have also been discussed in the literature.

Communication channel (Rogers, 1995), types of innovation (Goodhue and Thompson, 1995), nature of the social system, performance impact, and subject norms (Taylor and Tood, 1995) are also thought to be amongst the influencing factors. A study on the adoption of solar-powered irrigation systems found that different scales of farming (Smallholder, commercial, and subsistence) and several irrigation practices (fuel-based, grill-connected, and rained) need to be evaluated before examining the adaptation options (SNVNDO, 2014).

Despite the financial benefits, SPIS also has important impacts on people's living conditions. A study by the International Water Management Institute (2015) commented that the benefits of solar irrigation systems include increased social welfare (emissions reduction, poverty alleviation), improved livelihoods (increased incomes, productivity, and food security), and reduced spending on subsidized fuel and centralized infrastructure. Although scientific literature on the financial preferences (Sattar and Rahman, 2004; Hoque et al., 2016; Hossain et al., 2015; Khan and Pathik, 2014; Agrawal and Jain, 2010; Odeh et al., 2010 and Shah et al., 2014) of solar irrigation projects are abundantly found, very few of them, however, talk about the impact of SPIS on the farmers' livelihood status. Livelihood indicators can be categorized as social, technical, human, physical, natural, environmental, financial, or even economic (Green and Haines, 2002; Kamruzzaman and Takeya, 2008; Lowe and Schilderman, 2001). This manuscript reports the results of a study carried out to shed some light on this area of concern.

2. Materials and Methods

2.1. Selection of sample and sample area

The study was conducted in cooperation with IDCOL at the Meherpur district of Bangladesh. Paddy growing farmers were interviewed from 12 July to 28 July 2019 with the help of the Resource Development Foundation (RDF), a local non-government organization (NGO). In this research, two types of farmers were considered, the target group and the control group. The target group was those who were involved in SPIS projects. Both category farmers were based on the community, and their livelihood depended on agriculture production. A well-designed questionnaire was used for collecting data about farm-level characteristics and the livelihood of farmers. Before conducting the study, pretesting and focus group discussions were conducted in the desired study area. A total of 140 farmers were interviewed of which, 80 farmers were SPIS users, and the remaining 60 were

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Table 1. List of abbreviation

FAO	Food and Agriculture organizations
MOA	Ministry of Agriculture
IDCOL	Infrastructure Development Company limited
SNVNDO	SNV Netherlands Development Organization
USAID	United States Agency for International Development
IWMI	International Water Management Institute
NGOs	Non-Government Organizations
IPM	Integrated Pest Management
HYV	High Yield variety

diesel pump users. Finally, 130 sample data (72 SPIS and 58 diesel pump users) were considered for analysis. The rest of the sample data was discarded due to incomplete information.

2.2. Analytical Tool

A binary regression model was used to discover the parameters influencing the adoption of solar-powered irrigation systems. Commonly, probit and logit models are used extensively in econometrics to formulate the functional relationship between the adoption probability and factors. Many studies were conducted using binary models to identify the determinants of single technology adoption (Mariano et al., 2012, Chuchird et al., 2017 and Karidjo et al., 2018). For this specific study, a probit model was used to identify the factors influencing the adoption of solar irrigation systems. The dependent variable has two categories in the probit model and is represented statistically by a probability distribution (Liao, 1994). The cumulative normal probability distribution is the foundation of probit analysis. The binary dependent variable, y, has 'zero' and one values (Aldrich and Nelson, 1984). For the analysis purpose, a farmer is considered an adopter who adopts SPIS and assigns a score of one, and 0 who used a diesel/electric powered irrigation system.

$$Y_i^* = Y_{ip} - Y_{iq} > 0 = \beta + \beta_i X_i + U_i$$

$$Where\ U_i \sim N\ (0, 1), i = 1 \ldots n$$

$$Y = 1\ if\ Y^* > 0, otherwise$$

Here, Y_i^* represents the adoption probability of SPIS, where Yip and Yiq represent SPIS adopters and non-adopters, respectively. β_i , represent the coefficient of the variable, where X_i represents the independent variable that influences the adaptation of the solar-powered irrigation system.

The empirical model for this analysis is below,

$$Y = \beta_0 + \beta_1 X_A + \beta_2 X_E + \beta_3 X_{FS} + \beta_4 X_{ES} + \beta_5 X_{AC} + \beta_6 X_I$$

Here Y stands for the probability of adoption (1= SPIS adopters, 0 otherwise), X_A = age of the respondent (years), X_E = Year of education (school year), X_{FS} = Total amount of cultivable land (hectare), X_{ES} = frequency of contact with extension personal, X_{AC} = Access to credit (1 = availability of credit, 0 otherwise), X_I = Income of the respondent (tk.).

2.3 Livelihood Index Analysis

The accuracy of the measurement of livelihood status depends on selecting an appropriate indicator and their issues. The present study attempted to identify six indicators potentially affected by the solar-powered irrigation project. These indicators were social capital, human capital, physical capital, natural capital, technical capital, and financial capital. Each type of capital had various sub-indicators yielding in different categories. Extensive pretesting and focused group discussions were conducted in the study area to select the capital index component. The details about the valuation of different livelihood indicators are presented in appendix A. The weighted capital index and composite livelihood index were prepared based on the principle of the multi-criteria analysis method (Nijkamp, 1990; Hyde et al., 2004). The concept of this method was studied from Sullivan et al. (2010). The formula for capital index and composite index is discussed below:

The capital index of each farmer was computed using the following formula.

$$CI = \frac{\sum W_i}{MS} \times 100$$

CI= weighted capital Index (Social capital, Human capital, Physical capital, Natural capital, Technical capital, and Financial capital).

W_i = Weighted of the ith individual issue of each capital obtained

MS = Number of individual items/issues of each capital multiplied by the maximum score assigned for individual issue.

The composite livelihood index of each respondent consisting of six capitals was expressed as bellows.

$$CLI_i = \frac{W_1HCI_i + W_2SCI_i + W_3NCI_i + W_4PCI_i + W_5TCI_i + W_6FCI_i}{W_1 + W_2 + W_3 + W_4 + W_5 + W_6}$$

CLI_i = Composite livelihood of ith respondents
HCI_i , SCI_i , NCI_i , PCI_i , TCI_i , FCI_i represent the weighted human, social, natural, physical, technical, and financial capital

$W_1 - W_6$ = Mean weight of respective capital derived by taking the average weights of all individual items/ issues.

2.4. Weighting scheme used for Composite capital analysis

Several studies (Murphy and John, 1996; Noble et al., 2010 and Sullivan et al., 2010) have reported using the weighting function to develop capital index in livelihood studies. Accordingly, each of the six major components was assigned with equal values. Similarly, the sub-components were also given equal weight within the component assuming that each component is coequal in contribution towards livelihood status.

3. Results

3.1. Factors affecting farmer decisions to adopt solar irrigation system

The result of probit analysis on finding factors responsible for adopting a solar irrigation system is presented in Table 2. It shows the omnibus test result mainly representing the likelihood ratio chi-square test. The objective of this testing is whether the model containing our set of predictors represents a significant improvement and is fed over an unconditional model with no predictors. Here, the omnibus test result indicates that our model containing the predictors represents a significant improvement and fit over the unconditional model. The R square result explains that the independent variable can explain nearly fifty percent of the change in the dependent variable. Table 2 shows that the coefficient of education was statistically significant and yielded a positive sign indicating that it leads to human capital development. This analysis supports the hypothesis that human capital has a positive role in evaluating and acquiring new technology. The coefficient of extension service contact had a significantly positive impact on the adoption of a solar-powered irrigation system. This finding acknowledges that farmers are likely to be influenced by the extension service's information since these sources are considered credible.

The co-efficient of farm size was found to significantly impact the decision on adopting a solar-powered irrigation system., however yielding negative signs. Here, the farm size was considered a proxy to the farmers' wealth, and the findings suggest that large farmers do not necessarily adopt a solar-powered irrigation system. Another variable, access to credit and off-farm income were also found to have a significant negative impact on the decision-making process. Farmers who had seemingly extra farm income tended towards investing in non-farm sources, which provided them larger returns than agriculture.

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Table 2. Result of Probit Model Regression

Variable	Estimate (S.E)	Margin Estimate
Constant	.988	
Experience	0.010 (0.018)	0.0017(0.003)
Education	.236***(0.078)	0.043***(0.013)
Farm Size	-0.032*(0.055)	-0.006*(0.009)
Family Size	.058 (0.109)	0.015(0.019)
Extension Service	.944** (0.368)	0.172**(0.06)
Access to Credit	-.676* (0.377)	-0.123*(0.065)
Off-Farm Income('000)	-0.0043*** (0.00009)	-0.0008***(0.00001)
Log likelihood Ratio (Omnibus test)	86.735	
R square	0.49	

(*, ** & *** indicate 10%, 5% and 1% level of significance respectively)

3.2. Livelihood capital indicators

The results of human capital indicators are shown in Table 3. The human capital index consists of four components. In the case of the knowledge about the profession, the target group's mean value was higher than the control group. A similar situation was found for health condition indicators. Better health conditions can be attributed to the government's better financial condition and awareness other variables represent that the maximum member of the target group had passed the primary education (Table 3), and some of the members have passed more than primary education. The majority of the control group members had passed primary education or below. Very few people attended secondary education. Better results of the target group on training received can be attributed to the constant training provided by the IDCOL to the solar-powered irrigation user.

Social capital was studied by analysing seven indicators. The mean value of the relationship with focused group personnel of agriculture and the relationship with other farmers was higher for target group people. In the same way, the mean value of social relations for the target group was also much higher than the control group. However, the mean value of a member of the co-operative organization, relationship with financial organizations was higher for the control group. Normally, control group people were involved in off-farm activities in the study area. Thus, they need to contact the financial organization more than target group people. This result is supported by Table 3, which proved that off-farm activities had a negative impact on adoption. Additionally, the control group had more local government participants than the target group participants. Findings also showed that the control group had a better relationship with the point of sale than the target group farmers, although their overall relationship with the point of sale was poor. It was also found that farmers in the study area usually sold their products to random buyers.

In natural capital, the mean value for compost pit, cow dung, and pit for the household was higher for the target group (0.14, 0.6, 0.34, and 2.31) than the control group (0.1, 0.54, 0.32, and 1.52, respectively). The result showed that farmers who used solar-powered irrigation systems are more aware of preserving and using organic material in the field. The study also revealed that the target group had better irrigation facilities in terms of irrigation cost, water availability, and labour requirement.

On the other hand, the control group had better housing facilities and agriculture implementation for physical capital. Most of the control group farmers had shallow pump machines. The income source of most of the control group farmers is related to off-farm activities. Thus, control group farmers had a better score in agriculture equipment and housing facility. However, solar-powered irrigation projects can be seen in sanitation and housing furniture, where little investment is required. The findings showed that the target group had a slightly better position in terms of sanitation facilities and furniture in the house.

In addition, most control group farmers had centrifugal pumps for shallow depth groundwater extraction. Moreover, sanitation facility and household furniture indices were higher for target group farmers. The study results also show (Table 3) that the target group people were better off in terms of technical capital and are conscious about soil health. Similarly, the target group had better production-related knowledge and information source than the control group. Farmers in the study area collected information mostly from retailers or other farmers about different production-related information. SPIS project beneficiaries, have easy access to the government expert about insecticide use and production methods. Thus, the target group had a better position in these two parameters (1.91 and 1.92, respectively).

In financial capital, the mean value of agriculture source income, livestock, and poultry were higher (2.37, 1.66, 1.38, 0.40, 0.42) for the target group, although quite similar to the control group (2.26, 1.62, 1.46, 0.3, and 0.54 respectively). The slightly higher income from agriculture sources can be attributed to the reduction in production cost and the development of farming methods due to constant training. In contrast, the mean value of off-farm income was higher for the control group, and this was expected as most of the control group farmers were involved in the off-farm activity. The result also showed that target group farmers were more interested in savings than the control group. Conversely,, the control group farmers had more credit facilities than the target group.

The weighted mean value of different capitals is presented in Table 4. The result revealed that solar-powered irrigation users had a better score in human capital, natural capital, technical capital, and financial capital than the control group . But, the score for physical capital was higher for control group farmers. The composite capital calculated by taking the weighted mean value of all capital was higher for target group people. The result indicated that farmers had developed their livelihood by adopting the solar-powered irrigation system in the study area, which is reflected in different livelihood capital.

Additionally, a mean independent t-test was conducted to test the significance of the difference between the weighted capital indicators. The result revealed that the target group's human, natural, and technical capital indices differ significantly (p=0.01) (Table 4). These three indicators reflect the impact of solar-powered irrigation systems on the development of farmers. Moreover, the significant difference in the composite capital score leads to the conclusion that there was a significant difference between these two groups of people.

4. Discussion

This study revealed the socio-economic factors affecting the farmers' adoption of solar-powered irrigation systems (SPIS). Findings showed that education, farm size, extension service contact, access to credit, and off-farm income significantly impacted adoption decisions. Particularly, education and extension service contact had a positive impact where farm size, access to credit, and off-farm income had negatively impacted the adoption decisions. The positive sign signifies the role of education in adopting the new technology in agriculture. Bacha et al. (2011), Chirwa (2005), and Huang & Karimanzira (2018) also reported similar findings from their respective studies.

According to the results of this study, the extension service contact has emerged as an important tool that determines the farmers' mind, although Rahman and Norton (2019) reported otherwise. Besides, , farm size had negatively influenced the farmers' adoption decision. This finding is consistent with Diiro and Sam (2015), Huang & Karimanzira (2018), and Demeke & Croppenstedt (1996) but is in contrast with Rahman, & Norton (2019), Chirwa (2005), and Isham (2002). Apparently, large farmers are still skeptical about investing in a new technology that is being operated on a small-scale basis only in Bangladesh. They do not feel encouraged to invest large amounts of money unless significant government support is provided. They would rather invest in the diesel-powered irrigation system they have been used to.

Moreover, finding on "off-farm income" are contrary to the findings of Chirwa (2005) but consistent with the finding of Alabi et al. (2014) and Makokha et al. (2001). These two results revealed financial insecuri-

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Table 3. Mean value of livelihood capital indicator.

Component	Solar Powered Irrigation System user	Diesel Powered Irrigation System User
Human Capital		
Knowledge about profession	2.042	1.94
Health condition	2.242	2.04
Educational status	1.242	1.08
Training Received	1.75	0.9
Social Capital		
Relationship with focused group personal of agriculture	1.34	1.22
Co-operation with farmer	2.51	2.3
Membership of co-operative organization	0.56	0.6
Social relation	2.7	2.38
Relationship with financial organization	1.5	1.86
Participate in local government	1.2	1.18
Relation with point of sale	0.78	0.84
Natural Capital		
Ownership of compost pit	0.14	0.1
Ownership of cow dung pit	0.6	0.54
Ownership of pit for household waste	0.34	0.32
Irrigation	2.31	1.52
Physical Capital		
Housing Facility	1.69	1.98
Sanitation Facility	1.87	1.78
Ownership of agricultural implement	1.94	2.14
Ownership of household furniture	2.19	2.06
Technical capital		
Improving soil health	0.96	0.86
Technical information source	1.56	1.24
Knowledge about insect and pest	1.91	1.72
Knowledge about production technology	1.92	1.68

Continue Table 3. Mean value of livelihood capital indicator.

Financial capital		
Agricultural income	2.37	2.26
Fisheries/livestock	1.66	1.62
Non-agricultural income	1.38	1.46
Savings	0.4	0.3
Credit availability	0.42	0.54

Table 4. Weighted value of different livelihood capital.

Component	Solar Powered Irrigation System User	Diesel Powered Irrigation System User
Human Capital	15.27 ***(4.064)	12.49
Social Capital	7.43 (NS) (1.821)	6.86
Natural Capital	14.07 ***(4.589)	10.56
Physical Capital	16.31 (NS) (-.463)	16.68
Technical Capital	13.29 ***(2.717)	11.74
Financial Capital	10.47 (NS) (1.735)	9.50
Composite Capital	13.52 ***(3.873)	12.01

(*, ** & *** indicate 10%, 5% and 1% level of significance respectively; NS represent "non-significant")

ty present in the agricultural sector. Farmers who had extra sources of income normally invest in the non-farm agriculture source as these sources are related to a higher return on investment.

In order to achieve the SGD goals, the government of Bangladesh is dedicated towards investing in renewable energy. To achieve this, target-based policies to promote SPIS adoption are needed. Since education has a positive role, the young farmers, in particular, should be offered vocational training. Extension services also need to be fortified as it has the biggest influence on the farming community. This study indicates that SPIS projects have failed to attract large farmers. Proper information and targeted extension contact may help encourage large farmers. In such cases, crop insurance policy can also be introduced to safeguard their income. The negative influence of credit access and off-farm income reveals that agriculture is still a subsistence sector in Bangladesh.

The second part of the study represents the impact of solar-powered irrigation systems on the farmers' livelihood. In order to study the effect, the livelihood capital indicators between the solar-powered irrigation system and the diesel-powered irrigation system were compared. Six capital indicators were selected. Findings revealed that all the components of human capital for solar-powered users had the upper hand over diesel-powered users. Human capital development can relate to the continuous contact of NGOs and regular government agency training. SPIS users also had better social, natural, technical, and financial capital. However, diesel-powered irrigation users had better housing and agricultural equipment than SPIS users. These findings indicate that SPIS farmers have developed their human, social, natural, financial, and technical capital. These developments can be related to the gain from SPIS projects in financial, training, and other facilities.

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5. Conclusion

This study reports the results of a study to explore the factors that affect the adoption of solar-powered irrigation systems (SPIS). It also reports the effect of SPIS projects on the livelihood standard of the farmers in the studied area. A total of 140 farmers were interviewed in this regard. We analysed the intervention of this project on the different capital components. This study concludes that farm-level socio-economic character influences farmers' adoption of solar irrigation systems. Among them, education and "extension services contact" had a significantly positive role in adopting SPIS. Besides, access to credit, farm size, and off-farm income negatively impacted the adoption process.

This study also concluded that SPIS projects positively impacted on the farmers' livelihood status, particularly on the development of human, social, natural and technical capital. The significant difference in the composite capital score led to the conclusion that SPIS had a substantial impact on the development of the livelihood status of farmers. This study recommends that further inquiries be made to understand the dynamics of adoption amongst the large farmers.

Conflict of Interest

The Authors declare no conflict of interest.

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Appendix A. Valuation of livelihood Index

Human Capital	
Parameter	**Score**
Knowledge About Main Profession	1.1-4 answers correctly; 2. 5-7 answers correctly; 3. 8-10 answers correctly;
Health Condition	0. Seriously sick; 1. Poor health condition; 2. Moderate health condition; 3. Good health condition.
Education Status	0. No education; 1. can sign or maximum 5 years; 2. complete education between 6-10 year; 3. complete education more than 10 years.
Degree of training received	0. No training; 1. minimum 1-day training; 2. minimum two training; 3. more than two training.
Social capital	
Relationship with focused group personal of agricultural	0. No visited either agriculture office or livestock office or any agricultural research centre or bank; 1. Visited one organization; 2. Visited two organizations; 3. Visited three or more than organization.
Extent of Co-operation with Farmers	0. No co-operation; 1. Poor co-operation; 2. Moderate co-operation; 3. Always co-operation.
Membership of co-operative organization	0. No membership; 1. Member of one organization; 2. Member of two organizations; 3. Member of three or more organizations.
Social relations	0. No visit; 1. Once in a year; 2. Visit in every half year; 3. Visit in every 4th month; 4. Visit in every month.
Relationship with point of sale	0. No co-operation; 1. Poor co-operation; 2. Moderate co-operation; 3. Always co-operation.
Relationship with financial institutions	0. No visit; 1. Once in a year; 2. Visit in every half year; 3. Visit in every 4th month; 4. Visit in every month.
Participation in Local government	0. No participation; 1. Minimum participation; 2. Average participation; 3. Frequent participation; 4. Always participation.

Continue Appendix A. Valuation of livelihood Index

Human Capital	
Parameter	**Score**
Natural Capital	
Ownership of Composite Pit	0. No ownership; 1. ownership
Ownership for Pit for Cow Dung	0. No ownership; 1. ownership
Ownership of Pit for Household Waste	0. No ownership; 1. ownership
Irrigation	1. Low satisfied; 2. Moderate satisfied; 3. High Satisfied.
Physical Capital	
Housing facility	0.No housing; 1. owned either bamboo made wall + straw thatched roof + muddy wall or muddy floor + corrugated sheet or muddy wall+ corrugated sheet roof + muddy floor type house; 2. either corrugated sheet or muddy wall + corrugated sheet roof + muddy floor house; 3. either owned brick wall + corrugated sheet or concreate roof +concreate floor house.
Sanitation facility	0.No housing; 1. either ring slab or open pit + bamboo made wall or plastic bag surroundings + straw thatched roof; 2. either ring slab + corrugated sheet wall + corrugated sheet roof; 3. concreate sanitation facility.
Ownership of Household Furniture	0.No ownership; 1. total value of furniture didn't exceed 15000tk; 2. total value of furniture found between 15000 to 40000 tk; 3. total value of furniture more than 40000 tk
Ownership of agricultural implement	0. No ownership; 1. at least 1 agricultural implement owned; 2. at least two agricultural implement owned; 3. more than two agricultural implement owned.
Ownership of livestock and poultry	0.No ownership; 1. total value of livestock and poultry didn't exceed 10000tk; 2. total value of livestock and poultry found between 10000 to 50000 tk; 3. total value of livestock and poultry more than 50000 tk
Technical Capital	
Improving of soil health	0. No measure either cow dung or crop residual, mulching crop; 1. Minimum (only use cow dung); 2. Cow dung and residual; 3. Only mulching.
Receiving of technical information	0. No use information; 1. Use of only source; 2. Use of two sources; 3. Use of three sources; 4. Use of more than three sources.
Knowledge of insect and pest	0. No knowledge; 1. Minimum knowledge (have knowledge common insect and pest); 2. Moderate knowledge (have knowledge about all insect and pest of rice); 3. Sufficient knowledge (have knowledge about pest and insect control); 4. Complete knowledge. (knowledge about everything including IPM).
Knowledge about production technology	0.No knowledge; 1. Local production technology; 2. Have knowledge about local production technology and HYB/production technique; 3. Have knowledge about local production technology, HYB production technique; 4. Complete knowledge about production technology and use modern technology
Return from agricultural produce.	0. No return; 1. Up to 25000 tk; 2. Between 25000 to 50000 tk; 3. more than 50000 tk

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Continue Appendix A. Valuation of livelihood Index

Human Capital	
Parameter	**Score**
Return from livestock-poultry and their products.	0. No return; 1. Up to 10000 tk; 2. Between 10000 to 25000 tk; 3. more than 25000 tk
Return from non-agricultural sector	0. No return; 1. Up to 50000 tk; 2. Between 50000 to 150000 tk; 3. more than 150000 tk
Savings	0. No Savings; 1. Up to 1000tk per month; 2. Between 1000 to 5000 tk; 3. more than 5000 tk
Credit receive	0.No availability of credit for agriculture; 1. Available credit facility for agriculture

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Can the world produce more rice without harming the environment?

Rice is the essential food crop of the developing world and the staple food of more than half of the world's population. As the population continues to increase, the demand for rice is growing too.

However, rice production has a negative environmental impact. According to the Environmental Defense Fund (EDF), **it releases damaging greenhouse gases into the atmosphere**, doing as much harm as 1,200 average-sized coal power stations, according to the Environmental Defense Fund (EDF). Besides, rice production requires a massive amount of water and labor.

Therefore, the real challenge now is to increase rice production while at the same time decreasing the environmental impact.

Comprehensive global research has been launched to evaluate the roadmaps toward sustainable intensification for a more prominent global rice bowl. The research was published on *Dec. 9 in Nature.*

The study aimed at comparing rice cropping systems around the world in terms of productivity and efficiency in applied inputs, which can help identify opportunities for improvement.

Several parties led this global assessment: Huazhong Agricultural University and the University of Nebraska-Lincoln, in collaboration with the University of California, Davis, and Texas A&M's AgriLife Research Center in the United States; the International Rice Research Institute; Africa Rice Center; Indonesian Center for Rice Research and Assessment Institute of Agricultural Technology in Indonesia; the Federal University of Santa Maria and EMBRAPA Arroz e Feijão in Brazil; National Institute of Agricultural Research in Uruguay; and Indian Institute of Farming Systems Research and Indian Institute of Water Management in India.

The results showed an optimistic hope of a sustainable room to increase rice production and reduce the negative environmental impact. In other words, there is still a possibility of achieving high yields with a small environmental impact per unit of production. These results give hope to many populations that depend on rice as an essential food resource.

1. Shen Yuan, Bruce A. Linquist, Lloyd T. Wilson, Kenneth G. Cassman, Alexander M. Stuart, Valerien Pede, Berta Miro, Kazuki Saito, Nurwulan Agustiani, Vina Eka Aristya, Leonardus Y. Krisnadi, Alencar Junior Zanon, Alexandre Bryan Heinemann, Gonzalo Carracelas, Nataraja Subash, Pothula S. Brahmanand, Tao Li, Shaobing Peng, Patricio Grassini. Sustainable intensification for a larger global rice bowl. Nature Communications, 2021; 12 (1) DOI: 10.1038/s41467-021-27424-z

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The continued global warming could lead to an elevation of the sea level by as much as five meters by the year 3000 CE

The retreat of the Earth's ice sheets and glaciers is one of the enormous effects of global warming, which eventually leads to the rise of the sea level. Understanding the impact of climate change on populations is vital as rising sea levels will make large areas of densely populated coastal land ultimately become uninhabitable.

Researchers from Hokkaido University, The University of Tokyo, and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) used different models to investigate the long-term effect of global warming on the Antarctic ice sheet beyond the 21s, assuming late 21st-century climatic conditions remain constant. Their models and conclusions were published in the Journal of Glaciology.

The Ice Sheet Model Intercomparison Project for the Coupled Model Intercomparison Project Phase 6 (ISMIP6) was a significant international effort that used the latest generation of models to estimate the impact of global warming on the ice sheets of Antarctica and Greenland. The objective was to provide input for the recently published Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC). The study assessed the effect of the Antarctic ice sheet in sea-level rise by 2100 to be between 7.8 and 30.0 centimeters under unabated warming and between 0 and 3 centimeters under reduced emissions of greenhouse gases.

The results of this study demonstrate clearly how the most severe impact of 21st-century climate change on the Antarctic ice sheet will likely only be seen later. Future work will include basing simulations on more realistic future climate scenarios and using other ice-sheet models to model the outcomes.

1. Christopher Chambers, Ralf Greve, Takashi Obase, Fuyuki Saito, Ayako Abe-Ouchi. **Mass loss of the Antarctic ice sheet until the year 3000 under a sustained late-21st-century climate.** Journal of Glaciology, 2021; 1 DOI: 10.1017/jog.2021.124

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The ability of cannabis to absorb heavy metals that affect consumer health

Cannabis plants are used to produce industrial hemp. Hemp is usually used to make various commercial and industrial products, including rope, textiles, clothing, shoes, food, paper, bioplastics, insulation, and biofuel. Moreover, cannabis is used to produce medical marijuana and cannabidiol (CBD) oil, among other products.

The cannabis plants can soak up heavy metals from the soil, such as lead, mercury, cadmium, and chromium, making them helpful in remediating contaminated sites. However, this ability to absorb such toxic metals may also make those plants dangerous for consumers who ingest them.
A new meta-analysis study carried on by researchers at Penn State explores the ability of cannabis plants to absorb heavy metals and study the effect on consumers.

Heavy metals like mercury, cadmium, and chromium are known to be carcinogenic. The content of the heavy metals in cannabis is not regulated; therefore, consumers could unknowingly be exposed to these toxic metals. The previous finding is considered particularly problematic for cancer patients who use medical marijuana to treat the side effects of their treatments.

The researchers explained that heavy metals are rarely metabolized and accumulate in specific human body areas. Therefore, the heavy metal contamination in cannabis can cause various health problems. The most common mechanism of heavy metal toxicity in the human body is via the production of reactive oxygen species and free radicals, which can damage enzymes, proteins, lipids, and nucleic acids and cause cancer and neurological issues.

Moreover, the smoke from cannabis consists of selenium, mercury, cadmium, lead, chromium, nickel, and arsenic. Thus, cannabis consumed in a combustive form represents the greatest danger to human health.

The study demonstrated that the problem is currently considered at the consumer level who uses cannabis products, but the solution must come at the agricultural level.

1. Louis Bengyella, Mohammed Kuddus, Piyali Mukherjee, Dobgima J. Fonmboh, John E. Kaminski. **Global impact of trace non-essential heavy metal contaminants in industrial cannabis bioeconomy.** Toxin Reviews, 2021; 1
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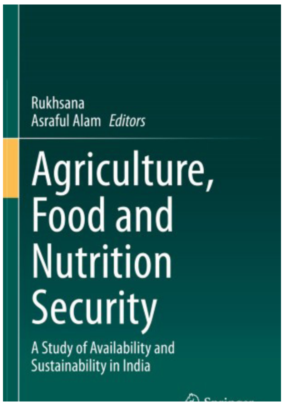

Agriculture, Food and Nutrition Security, A Study of Availability and Sustainability in India

A review by Nayram Ama Doe

Authors (Eds.): Rukhsana and Asraful Alam
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World Bank highlights the importance of agriculture regarding the availability and accessibility of individuals' food, income, and livelihoods. However, it is the main aspect to be considered in the improvement of food and nutrition security. Developing the agricultural domain is significant in mitigating poverty, especially in developing countries due to a significant part of GDP generation within the primary sector. This book consists of three main parts with different chapters in each part. This book discusses several interesting topics such as the impact of microclimate on agriculture in India, problems and prospects of food security in India, determinants of childhood stunting in India and many other topics.

This book's first part begins with a discussion on climate and agricultural productivity for availability. An overview of agriculture, food and nutrition security was discussed, presenting how global production of food has been very successful over the last four decades due to a major increase in this production level, but in the process, is the cause of the various climatic and environmental problems we face. In discussing availability, food security is one significant aspect that is considered. To attain food security, there was an assurance by the World Food Summit to decrease the number of malnourished people. Another interesting topic discussed in chapter three of this part was the impact of microclimate on agriculture. This book highlighted the influence of climate on ecological processes of nutrition cycle, plant regeneration, selection of wildlife habitat and soil respiration. Again, this book emphasized that climate change impacts the health of humans and is also catastrophic for food security and agricultural production because it is strictly dependent on water adequacy.

The second part of this book highlights cropping patterns and food security changes. India has impressively progressed in the agricultural sector during the last three decades despite a drastic increase in its population. This success is credited to the smaller household farming communities, better production strategies, public investment in policy support and various research have significantly aided in food production increase and availability. Despite the progress in agricultural productivity, there remains problems and challenges of food security. Climate is a critical factor in food production; hence the slightest change could influence production and food security. Higher temperatures could lead to heat waves occurrences, droughts, soil degradation and scarceness of water, melting of the cryosphere, consequential to an increase in the global sea level, which will, in the long run, affect food security. To achieve food security with these recurring problems, a country should produce and import needed food, store, distribute, and enable equal access to it.

The third and concluding part of this book climaxes sustainable food and nutrition security. It seeks to understand the multidimensions of food and nutrition security in Odisha, discussing an integrated availability, accessibility, and utilization approach. Furthermore, it enlightens readers on the determinants of stunting in India, giving comparative evidence from Bihar. Notwithstanding, a sibling effect on intra-household child malnutrition in India is discussed, analyzing different sociodemographic groups from the national family health survey.

In general, this book was very enlightening, educative, and informative as it presents and highlights many facts about agricultural production and food security and how climate is very significant and a high determinant for effective agricultural production and food security. This book is very

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educative and informative and is highly recommended as a perfect read and helpful resource in the area of agriculture and food security.

About the author:

Nayram Ama Doe is a master's student at the University of Kassel and Fulda University of Applied Sciences, Germany, studying International Food Business and Consumer Studies. Her research focuses on food sustainability, international food legislation, agriculture, and food systems, and she is very passionate about food security and food supply chain issues.

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