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Automated Conveyor System of Sorting and Grading for Red Chili Pepper (*Capsicum annum* L.) using Image Processing and Artificial Neural Network

Hanis Adila Lestari[1], Anri Kurniawan[1,✉], Luthfi Wahab[1]

[1] Departement of Agricultural and Biosystem Engineering, Faculty of Science and Technology, Nahdlatul Ulama University of Purwokerto, INDONESIA.

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Corresponding Author:
✉ anrykurniawan1991@gmail.com
(Anri Kurniawan)

ABSTRACT

This research aims to design an automatic sorting and grading tool driven by color sensor processed through image processing and artificial neural networks (ANN). The research stage consists of data collection in a Mini Studio, image processing using ImageJ, and image classification with ANN. The automatic sorting process begins with items entering the belt, where they are processed in four phases: (1) separating good and rejects chili, (2) separating red from green chili, (3) distinguishing large and small red peppers, and (4) separating large and small green peppers. Automatic sorting and grading were based on image data processed using ANN. The best activation function was tansig-logsig-purelin with MAPE 1.220, RMSE 0.010, and R^2 = 1 during training. During testing, the MAPE 0.158, RMSE 1.790, and R^2 = 0.963. The criteria produced grade 1 (red, 10-15 cm), grade 2 (green, 10-15 cm), grade 3 (red, 5-9.99 cm), and reject grade. The quality of large red chilies is used as a reference for market pricing: grade 1 (IDR 60,000/kg), grade 2 (IDR 40,000/kg), and grade 3 (IDR 25.000 – 35,000). Assessing quality based on color with an automatic conveyor can reduce sorting and grading time by 70% compared to conventional methods.

1. INTRODUCTION

The fruit vegetable, red chili pepper (*Capsicum annum L.*) adds more spiciness to food and serves as the main ingredient to make sauce and sambal (Tang *et al*., 2023). It is one of the horticultural commodities with a high economic value and contributes largely to Indonesia's Gross Domestic Product (GDP). It is priced relatively high at IDR 150,000.00, especially at the year's end or on holy days. The data are considerably high, considering red chili pepper production in Central Java only achieves 502,838 quintals (Luthfi *et al*., 2023). The harvested chili peppers' grade determined the price of red chili peppers in May 2024. As indicated by data from regional.kompas.com, the price of red chili peppers (grade 1) is IDR 60,000.00/kg, while green chili peppers are priced at IDR 40,000.00/kg and small red chili peppers (grade 3) are IDR 25,000.00-IDR 35,000.00/kg.

The post-harvesting period of red chili pepper is deemed critical as it is when a high level of damage may come about, i.e., 0.8%-10.6%, because of constrained facilities and farmers' knowledge about handling the post-harvesting process (Khafit *et al*., 2023). The process consists of sorting and grading, which are crucial since the market price of the commodities is defined following their quality or grades, made up of super grade, green grade, and super small grade. Sorting and grading activities can be performed by taking into account physical, chemical, and biological factors. Among the physical factors considered are color, weight, shape, size, and content (Getahun *et al*., 2021).

The sorting process of red chili peppers by color takes three colors into account, namely red, greenish-red, and green (Moya *et al*., 2024), while the grading process is concerned with four grades, which are grade I, grade II, grade

III, and reject. The reject grade is given to red chili peppers with the following characteristics: small, striped, rotten, with holes, irregular in shape, and pest-and-disease affected. Grading can be performed by developing image processing and Artificial Neural Network algorithms (Khuriyati *et al*., 2019).

The current sorting and grading of red chili peppers remain conventional by hand, which comes with several drawbacks, particularly related to the output lacking precision. Human work has limitations and often brings on negligence if conducted long on a large quantity of products (Iwan *et al*., 2022). Accordingly, sorting and grading technologies are expected to lessen faults, engendering quicker and more accurate outputs (Shao *et al*., 2024). A conveyor, a tool invoked in the sorting and grading process, allows for more effective and efficient performance and offers an automatic control process in its application (Akila *et al*., 2019). Automatic grading using a conveyor can accelerate the work process by 70% compared to conventional methods.

Image processing processes images or digital images to obtain useful data for analysis, manipulation, or broad understanding. The process encompasses pra-processing, segmentation, extraction, object detection, image restoration, and image analysis (Khuriyati *et al*., 2020). Image processing can be applied in diverse activities, e.g., inspecting fruit quality and detecting defects or damage (Ghuge *et al*., 2023). Meanwhile, the Artificial Neural Network is a technology for classifying images to generate the desired decisions, such as on fruit maturity levels.

Research on image processing is undertaken by Sihombing *et al*. (2022) and Simanungkalit & Manurung (2024), who analyzed the application of ANN on bananas. Another relevant research is by Mohi-Alden *et al*. (2023), who deploy image processing to sort bell peppers, Subrata & Baiquni (2024), and Abubeker *et al*. (2023), who investigate red chilis. Thinh *et al*. (2020) embed image processing in the mango detecting system, while (Zhou *et al*., 2023) employ it with a conveyor. Hendrawan *et al*. (2021) perform image processing to observe green chili maturity, while Asian *et al*. (2024) and Chen *et al*. (2024) employ it in chili pepper classification.

Based on the issues, a specific technology enabling quicker and more accurate sorting and grading with precision agriculture concepts is called for. This research focuses on designing a sorting tool, which is a mini conveyor by taking color, size (using the RGB method), and grades of red chili peppers (grades I, II, III, and reject) into account. The grading and sorting process for large red chilies is necessary to improve work efficiency, especially by using an automatic conveyor system, which can enhance productivity. In addition, it increases processing speed, ensures consistent and standardized results, reduces labor, and improves product quality in accordance with market demands.

2. MATERIALS AND METHODS

2.1. Tools and Materials

Several exploited tools were a Redmi Note 10 Pro smartphone camera, mini studio, laptop, and control system circuit (TCS230 Color Sensor, Arduino Mega, Servo Motor, and potentiometer). Meanwhile, the conveyor was composed of a belt, DC motor, gearbox, roller, idler roller, head pulley, sensor bracket, converter, and power supply. The software leveraged was MATLAB, Arduino IDE, ImageJ, and ColorMine and Color Converter applications. The measurement tools used were a caliper, ruler, Linshang 171 colorimeter, and timer scale.

The materials utilized were red chili peppers (Pilar F1 variety) from Bojonggambar, Tasikmalaya, West Java, red chili peppers (Boostavi F1 variety) from Rempoah, Baturraden, Banyumas, Central Java, and red chili peppers (Baja F1 variety) from Penolih, Kaligondang, Purbalingga, Central Java. Red chili peppers were graded into four grades, i.e., grade I, grade II, grade III, and reject, and each grade comprised 100 samples from each village, totaling 300 samples which consisted of 201 training and 90 testing.

2.2. Research Stages

2.2.1. Grade of Red Chili Peppers

Red chili peppers were categorized into three colors, namely green, red, and greenish-red (Subrata *et al*., 2022). For the green color, the R-value was 135-235, the G value was 191-337, and the B value was 181-247, while for the red one, the R-value was 135-255. The R and G values of the greenish-red color were 135-235 and 191-235, respectively (Tosi *et al*., 2024). Table 1 displays more detailed information regarding the size and data on red chili peppers' grades.

Table 1. Chili Pepper Grade Parameters

Parameters	Grades			
	I	II	III	Reject
Colors	Red	Green Greenish-red	Red	Red Green Greenish-red Blackish-red
Size	> 10 cm	> 10 cm	5-9.9 cm	All sizes > 20 cm < 5 cm
Conditions	No defects	No defects	No defects	Black, white, and brown defects Imperfect shape

Red chili peppers classified as reject were broken, affected by pests or diseases, small (<5 cm), irregular in shape, rotten, and striped (Harel *et al*., 2020). Following the reference, after the post-harvesting process, ten types of red chili peppers at many different maturity levels (Figure 1) could be identified (Prayogi *et al*., 2022).

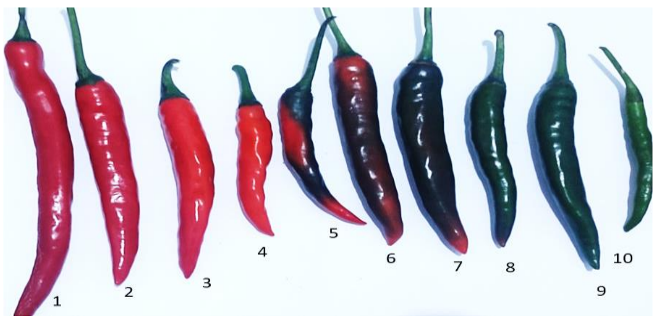

Figure 1. Classification of chili pepper maturity: (1, 2) big red chili pepper; (3, 4) small red chili pepper; (5, 6, 7) greenish red chili pepper; (8, 9) big green chili pepper; (10) small green chili pepper

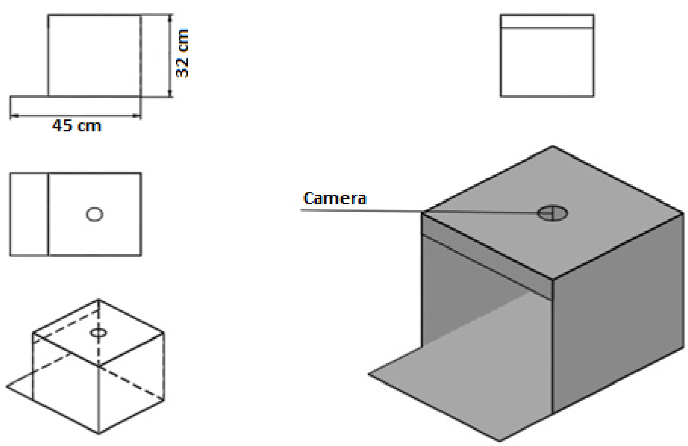

Figure 2. Mini studio design

2.2.2. Sampling

The sampling process was undertaken by picking classified red chili peppers and collecting data in the following steps. The Mini Studio is used with lighting at 800 lux, featuring a white background with dimensions of 45cm x 32cm x 32cm, and a smartphone camera is positioned at the top opening (Figure 2). Red chili peppers, set in a mini studio, were pictured one by one, starting from grades 1, II, and III to reject using a Redmi Note 10 Pro smartphone camera at a resolution of 105 MP (Luthfi *et al*., 2023). The mini studio's background should be white to optimize the light and reduce shadows. The next steps were storing the images acquired in folders tagged as Large Red Chili Peppers, Small Red Chili Peppers, Green Chili Peppers, and Reject. Figure 3 shows image processing steps.

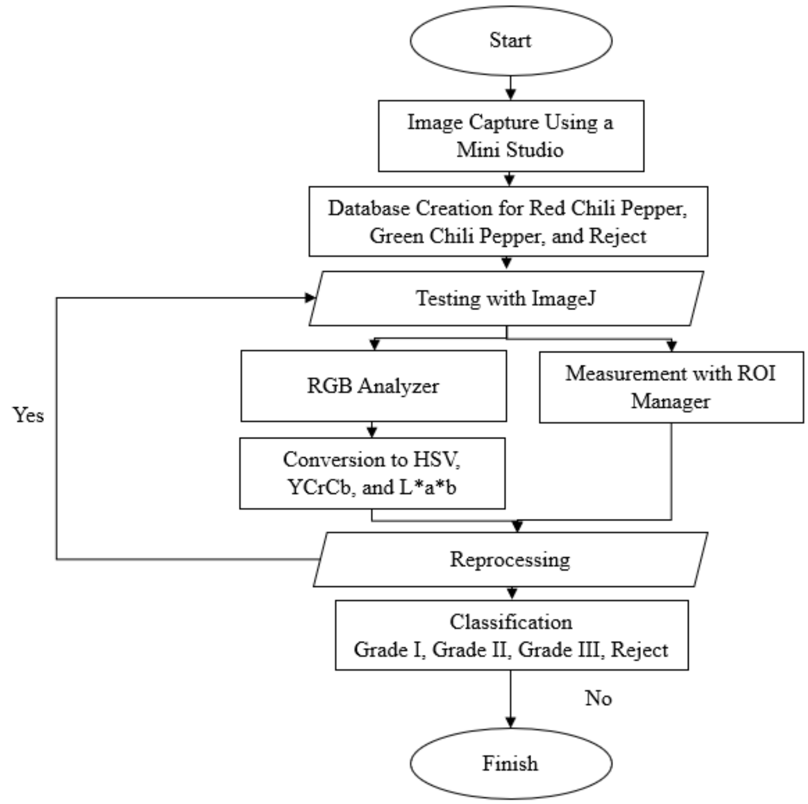

Figure 3. Image processing flowchart

The Red, Green, and Blue (RGB) values were then identified using the RGB analyzer feature of the ImageJ application, and data on the colors were converted into Hue Saturation Values (HSV) and YCrCB values using ColorMine and Color Converter applications. Meanwhile, the L*a*b value was determined using a colorimeter (Hadinegoro & Rizaldilhi, 2021). The images were subsequently processed to identify chili peppers' sizes, covering their lengths and diameters, using Image Acquisition and the ROI manager. Large chili peppers came with a size of > 10 nm, while small ones had a size of 5-9.9 cm. Those of < 5 cm were categorized as reject.

2.2.3. Automation Sorting and Grading Design

The designing process underwent several other processes, such as literary study, problem analysis, design determination, tool testing, and evaluation. The design follows some references on conveyors utilized in sorting and grading processes, e.g., those applied by Akila *et al*. (2019), on sweet oranges (Irwan *et al*., 2022), apples (Khafit *et al*., 2023), curly chili peppers (Sari *et al*., 2021), and tomatoes (Hetharua *et al*., 2021). After a simulation using Autodesk AutoCAD 2025 was carried out, the image of automatic sorting and grading tools was produced, as pointed out in Figure 4. Automation sorting and grading of chili pepper was a mini conveyor (Figure 5) with a control system in the form of a TCS2300 color sensor input, which would detect data transferred to Arduino Mega and give commands to the output for execution (Khan *et al*., 2023). The system outputs were two servo motors, which acted as sorters 1 and 2 and later the determiners in the sorting and grading process for red chili peppers. Sorting and grading processes were conducted in four iterations with different criteria presented in Table 2.

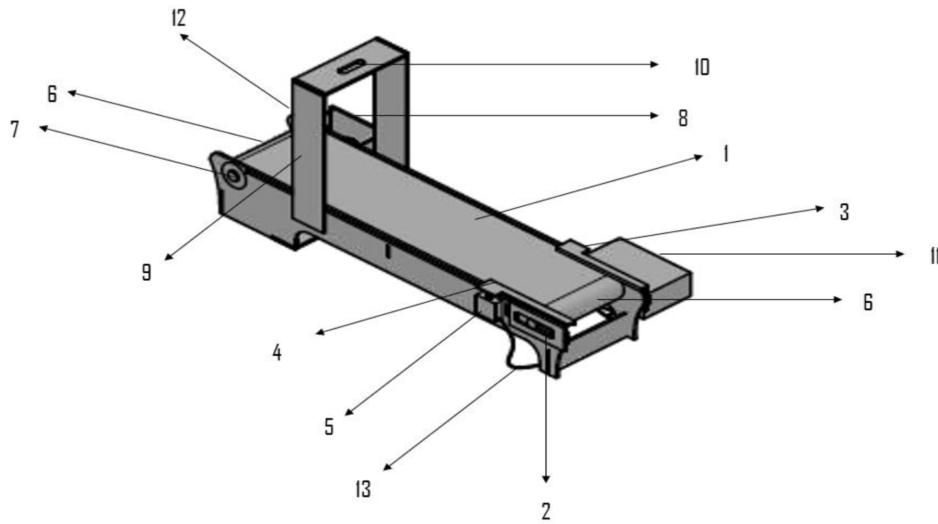

Figure 4. Conveyor for sorting and grading: 1) Belt, 2) DC motor and Gearbox, 3) Servo 1, 4) Servo 2, 5) Power Supply, 6) Roller, 7) Idler roller, 8) Potentiometer, 9) Sensor Bracket, 10) TCS230 Sensor, 11) Control Box, 12) Converter, 13) Adaptor Charger

Figure 5. Conveyor sorter: top view (left), and front view (right)

Table 2. Decision-making criteria

No.	Process	Input Criteria	Sorter 1	Sorter 2
1	Sorting 1	Red chili peppers Green chili peppers Striped chili peppers Damaged chili peppers	Red chili peppers Green chili peppers	Damaged chili peppers Striped chili peppers
2	Sorting 2	Red chili peppers Green chili peppers	Red chili peppers	Green chili peppers
3	Grading 1	Red chili peppers	Large red chili peppers	Small red chili peppers
4	Grading 2	Green chili peppers	Large green chili peppers	Small green chili peppers

2.3. Research Process

2.3.1. Research Parameters

The independent variables (x) were x_1 = the RED value, x_2 = the GREEN value, x_3 = the BLUE value, and x_4 = chili peppers' length, while the dependent variables (y) included chili peppers' grades, namely grades I, II, and III. The y values not included in the three grades were categorized as reject. In the training process, the number of samples was 210 data, 90 testing data, four nodes in the input layer, four nodes in the hidden layer 1, four nodes in the hidden layer 2 nodes, and one node in the output layer 1. The learning rate value was 0.1 with the logsig, tansig, and purelin activation functions with 27 variations.

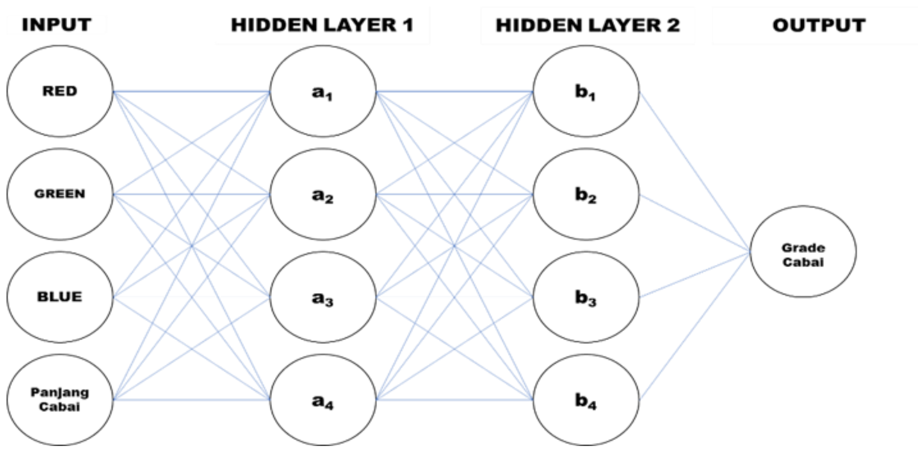

Figure 6. Architecture of the Artificial Neural Network for chili pepper sorting and grading

Figure 7. Conversion of the ANN program to Arduino process

2.3.2. Conversion of the ANN Program to Arduino

The completed ANN program, with obtained values for RMSE, MAPE, and the Coefficient of Determination (R^2), is then used as a reference for the Arduino program embedded in coding within the Arduino IDE. The conversion process can be seen in Figure 7. The research process flowchart is shown in Figure 8.

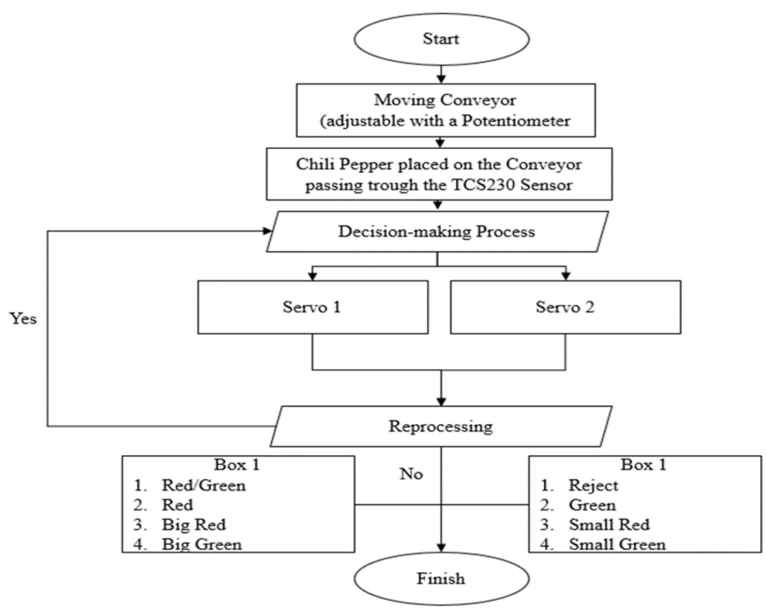

Figure 8. Sorting and grading flowchart

2.4. Data Analysis

Data were analyzed based on accuracy parameters using the Root Mean Square Error (RMSE), Mean Average Percentage Error (MAPE), and the coefficient of determination (R^2) using Microsoft Excel 2019.

$$\text{RMSE} = \left(\frac{\sum(y_i - \hat{y}_i)}{n}\right)^{1/2} \tag{1}$$

$$\text{MAPE} = \sum_{t=1}^{n}\left|\frac{y_i - \hat{y}_i}{\hat{y}_i}\right| \times 100\% \tag{2}$$

3. RESULTS AND DISCUSSION

3.1. Red Chili Pepper Image Processing

Data measurement with ImageJ consisted of two processes. To begin with, data on color for RGB value identification were collected using the polygon feature in cropping red chili pepper images. Red, Green, and Blue (RGB) values were acquired using the "RGB measure" plugin and converted into HSV, YCrCb, and L*a*b values to determine red chili pepper maturity rates.

The next process included data collection to measure the areas of chili peppers, with their length (cm) as the reference in the grading process. The initial steps were to set the size scale of the image, adjust the image using the Color Threshold, and brush the area of chili peppers to be measured with the red color. The ROI manager value was obtained using the wand tool applied to the area set for measurement.

Table 3. RGB measurement results

No.	R	G	B	L	a	b	Y	Cr	Cb	H	S	V	Length	Grade
1	120.837	48.450	63.755	30.811	33.136	6.495	77	159	124	348	0.60	0.471	10.804	1
2	142.598	57.726	63.810	36.310	36.540	14.631	87	165	118	356	0.60	0.56	10.970	1
3	149.132	65.638	72.902	39.132	35.796	12.929	94	164	119	355	0.56	0.58	14.315	1
4	137.822	59.369	74.679	36.095	34.994	73.036	88	161	123	348	0.57	0.54	13.699	1
5	123.448	50.837	66.685	31.805	33.194	6.049	79	159	124	347	0.59	0.48	12.975	1
6	130.179	47.834	61.374	32.261	36.641	10.318	79	163	122	350	0.64	0.51	12.465	1
7	140.016	51.123	63.957	34.651	38.839	12.209	84	166	120	352	0.64	0.55	12.928	1
8	135.076	68.470	85.300	37.859	30.334	30.353	93	156	126	345	0.50	0.53	11.576	1
9	130.034	57.616	72.312	34.412	32.733	6.258	85	159	124	348	0.56	0.51	12.378	1
10	136.608	69.024	83.489	38.158	30.383	4.634	94	156	124	347	0.49	0.53	11.612	1
11	140.211	67.920	80.182	38.376	31.971	7.099	94	159	123	349	0.52	0.55	11.393	1
12	130.333	57.416	68.515	34.321	32.531	8.573	85	159	122	351	0.56	0.51	11.846	1
13	132.592	50.853	66.539	33.367	36.539	8.569	82	163	123	348	0.62	0.52	14.636	1
14	125.424	48.127	64.167	31.551	35.040	7.383	79	161	124	348	0.62	0.49	14.696	1
15	131.438	46.055	61.962	32.182	38.000	9.861	79	164	122	349	0.65	0.51	14.511	1
16	151.982	61.784	72.919	38.856	38.800	12.614	93	167	120	353	0.60	0.59	12.628	1
17	139.154	69.985	86.756	38.838	31.242	3.609	95	158	125	345	0.50	0.55	13.238	1
18	136.572	66.382	83.050	37.570	31.767	4.067	92	158	125	345	0.52	0.53	12.618	1
19	124.002	46.797	61.157	30.975	34.876	8.507	77	161	123	348	0.63	0.49	11.686	1
20	122.870	57.601	71.017	33.227	29.846	5.249	83	156	125	347	0.53	0.48	11.265	1
21	128.318	61.486	79.318	35.148	30.837	2.788	87	156	126	344	0.52	0.5	13.513	1
22	146.035	71.520	85.367	40.162	32.851	6.509	98	160	123	349	0.51	0.57	12.915	1
23	133.254	54.368	69.969	34.235	35.369	7.589	84	162	123	349	0.59	0.52	12.106	1
24	126.536	51.962	67.835	32.578	33.888	6.470	81	160	124	347	0.60	0.49	11.856	1
25	130.185	68.595	83.592	37.116	28.149	2.949	92	154	125	345	0.48	0.510	12.265	1
26	122.688	44.223	58.368	30.194	35.393	9.218	78	161	123	328	0.64	0.48	11.509	1
27	131.422	53.738	68.467	33.766	34.856	7.852	83	161	123	348	0.60	0.51	11.694	1
28	136.810	69.114	83.181	38.199	30.372	4.891	94	156	124	347	0.49	0.53	11.457	1
29	138.170	54.014	59.740	34.764	36.391	15.005	84	165	118	356	0.61	0.54	10.899	1
30	131.655	60.408	80.008	35.463	32.769	2.868	88	158	126	343	0.54	0.51	10.313	1
31	36.946	54.842	53.730	21.482	-7.519	-1.649	58	120	130	177	0.33	0.21	10.724	2
32	47.988	69.391	77.132	28.035	-6.089	-7.329	70	118	135	196	0.39	0.3	12.688	2

Table 3. RGB measurement results (continued)

No.	R	G	B	L	a	b	Y	Cr	Cb	H	S	V	Length	Grade
33	41.908	64.989	71.506	25.954	-7.002	-6.817	66	117	134	194	0.42	0.28	12.422	2
34	34.800	60.849	62.665	23.772	-9.393	-4.274	61	116	133	184	0.45	0.24	12.336	2
35	31.484	54.066	61.729	21.163	-6.426	-7.582	57	117	134	194	0.49	0.24	12.675	2
36	30.301	55.252	54.209	21.227	-9.939	-2.396	57	117	131	178	0.46	0.22	11.853	2
37	30.470	54.878	55.477	21.149	-9.262	-3.371	56	117	132	182	0.46	0.22	12.838	2
38	37.564	61.469	64.547	24.219	-8.318	-4.842	63	117	133	187	0.42	0.25	11.584	2
39	34.749	56.899	60.101	22.290	-7.715	-4.767	59	118	133	189	0.43	0.24	10.938	2
40	34.355	53.124	57.925	20.860	-6.091	-5.439	57	119	133	190	0.40	0.22	11.346	2
41	35.188	54.148	52.226	21.067	-8.146	-1.253	57	120	130	174	0.35	0.21	10.434	2
42	33.591	50.338	52.409	19.618	-6.222	-3.532	55	120	131	186	0.37	0.2	13.257	2
43	38.728	63.194	64.933	24.901	-8.896	-4.075	64	117	132	182	0.41	0.251	12.773	2
44	37.120	65.002	67.006	25.508	-9.902	-4.550	65	116	133	184	0.45	0.26	12.264	2
45	34.086	58.586	64.650	23.015	-7.574	-6.738	60	117	134	192	0.47	0.25	12.520	2
46	34.414	60.191	57.259	23.328	-1.073	-1.324	61	117	131	173	0.43	0.24	11.538	2
47	31.565	53.807	55.117	20.818	-8.338	-3.611	56	118	132	185	0.44	0.22	11.677	2
48	38.180	62.052	62.240	24.376	-9.165	-3.071	63	117	132	180	0.39	0.24	11.494	2
49	33.914	57.007	56.861	22.159	-9.043	-2.786	59	118	131	178	0.42	0.22	10.760	2
50	34.908	53.504	58.985	21.071	-5.821	-5.839	57	119	133	192	0.41	0.23	11.675	2
51	38.033	53.203	51.092	20.894	-6.794	-0.713	57	122	129	172	0.28	0.21	10.313	2
52	50.977	75.085	81.783	30.286	-7.284	-6.933	75	117	134	192	0.38	0.32	12.453	2
53	30.761	51.292	57.751	19.979	-6.148	-6.669	55	118	134	193	0.47	0.22	13.742	2
54	33.921	51.569	59.081	20.334	-4.856	-7.021	56	120	134	198	0.44	0.23	12.323	2
55	33.213	56.867	60.143	22.188	-8.183	-4.958	59	118	133	189	0.45	0.24	12.600	2
56	37.472	64.827	68.465	25.521	-9.238	-5.491	64	116	134	188	0.46	0.27	13.152	2
57	34.505	61.290	67.818	24.104	-8.140	-7.208	62	116	135	191	0.49	0.263	11.847	2
58	45.694	71.542	74.380	28.509	-8.984	-4.846	71	116	133	186	0.39	0.290	12.020	2
59	40.232	64.968	62.712	25.528	-10.131	-1.667	65	118	131	175	0.38	0.25	11.076	2
60	28.160	49.156	52.394	18.844	-7.333	-4.715	53	119	132	188	0.46	0.2	11.345	2
61	135.286	69.369	87.533	38.152	30.210	2.057	94	156	126	344	0.49	0.53	9.675	3
62	138.702	71.200	90.668	39.147	30.913	1.597	96	156	126	343	0.49	0.54	8.892	3
63	141.750	69.979	88.825	39.284	32.492	3.005	96	158	126	344	0.51	0.55	8.606	3
64	125.963	66.354	88.880	36.157	28.542	-1.869	90	152	129	338	0.47	0.490	8.513	3
65	143.945	72.828	91.004	40.283	32.044	3.127	98	158	126	344	0.50	0.56	8.037	3
66	133.921	68.131	88.414	37.705	30.498	0.828	93	155	127	342	0.49	0.52	7.155	3
67	134.122	66.865	85.697	37.378	30.911	2.072	92	157	126	343	0.51	0.53	7.199	3
68	123.080	64.171	85.309	35.130	28.157	-1.157	88	152	128	339	0.48	0.48	6.555	3
69	124.776	64.212	80.189	35.234	28.067	2.287	88	153	126	344	0.48	0.49	5.515	3
70	135.690	66.497	83.628	37.476	31.441	3.551	92	157	125	345	0.51	0.53	9.632	3
71	141.979	71.890	89.998	39.761	31.685	29.646	97	157	126	345	0.50	0.55	8.831	3
72	143.265	70.447	88.627	39.605	32.782	3.622	97	159	125	345	0.51	0.56	8.512	3
73	126.778	64.746	85.365	35.807	29.253	-0.138	89	154	128	340	0.49	0.49	8.616	3
74	145.888	71.828	88.255	40.282	32.976	4.878	98	159	125	346	0.51	0.49	8.006	3
75	138.892	69.409	87.005	38.681	31.491	3.222	95	157	126	344	0.50	0.54	7.108	3
76	133.644	63.964	81.864	36.573	31.826	3.326	90	157	126	345	0.53	0.52	7.156	3
77	124.272	61.794	80.928	34.643	29.335	0.949	86	154	127	342	0.51	0.49	6.671	3
78	128.671	65.268	80.115	36.049	28.976	3.585	89	155	125	342	0.49	0.5	5.534	3
79	135.911	63.131	84.128	36.815	33.412	2.285	91	158	127	342	0.53	0.53	9.043	3
80	143.050	66.066	85.898	38.583	34.713	3.859	94	160	125	345	0.54	0.56	8.967	3
81	144.292	64.030	80.938	38.233	35.661	6.509	93	162	123	348	0.56	0.57	8.599	3
82	134.434	60.375	82.466	35.968	34.124	2.086	89	159	127	342	0.55	0.53	7.437	3
83	137.466	70.443	93.194	38.877	31.212	-0.401	96	156	128	339	0.49	0.54	6.627	3
84	132.951	60.382	81.364	35.702	33.435	2.374	88	158	127	342	0.55	0.52	7.297	3
85	140.456	66.342	86.738	38.262	33.708	2.815	94	159	126	344	0.53	0.55	6.875	3
86	131.859	77.944	97.837	39.938	25.505	-1.834	98	150	129	338	0.41	0.51	7.965	3
87	124.755	52.995	70.007	32.546	32.930	4.973	81	158	125	345	0.58	0.49	7.273	3
88	128.822	58.608	76.092	34.527	32.190	3.969	86	157	126	345	0.55	0.5	6.171	3
89	120.802	65.508	85.559	35.112	26.550	-1.382	88	151	129	338	0.46	0.47	5.232	3
90	135.479	66.665	79.178	37.358	30.718	6.187	92	157	123	349	0.51	0.53	5.755	3

3.2. Artificial Neural Network on Chili Peppers

The training and testing processes on chili pepper data were carried out using MATLAB to separate the criteria of grades I, II, and III using logsig, tansig, and purelin activation functions with 27 variations to acquire the desired results, as suggested in Table 4. The best activation function, as demonstrated in Table 4, was tansig-logsig-purelin. Tansig (hyperbolic tangent) transforms input values to a range of -1 to 1, with a symmetric function at the origin (0.0), resulting in positive values with better signal magnitude. On the other hand, logsig (logistic sigmoid) has flexibility with a range between 0 and 1, making it very suitable for classification expressed in probabilities. Purelin (linear) functions in the output layer handle regression values without limits, facilitating interpretation and computational efficiency. The use of the tansig-logsig-purelin combination is more effective in enhancing ANN performance than other activation functions due to the stability of the training process during backpropagation.

Table 4. ANN training and testing result

No.	Activation Functions	Training			Testing		
		MAPE	RMSE	R^2	MAPE	RMSE	R^2
1	logsig-logsig-logsig	1.400	0.010	1.000	3.880	0.229	0.9891
2	logsig-logsig-purelin	1.218	0.007	1.000	2.114	0.194	0.992
3	logsig-logsig-tansig	1.160	0.000	1.000	1.797	0.163	0.994
4	logsig-tansig-logsig	1.310	0.009	1.000	2.396	0.210	0.991
5	logsig-purelin-logsig	1.361	0.011	1.000	2.022	0.144	0.997
6	tansig-logsig-logsig	1.350	0.009	1.000	2.683	0.213	0.991
7	purelin-logsig-logsig	1.350	0.009	1.000	2.683	0.213	0.991
8	tansig-tansig-tansig	1.277	0.008	1.000	1.059	0.079	0.999
9	tansig-tansig-purelin	1.190	0.005	1.000	1.637	0.148	0.995
10	tansig-tansig-logsig	1.459	0.009	1.000	1.790	0.141	0.996
11	tansig-purelin-tansig	126.000	1.581	N/A	108.330	1.581	N/A
12	tansig-logsig-tansig	1.126	0.004	1.000	2.250	0.210	0.9907
13	purelin-tansig-tansig	1.580	126.000	N/A	ERR	108.330	N/A
14	logsig-tansig-tansig	1.261	0.006	1.000	2.220	0.191	0.992
15	purelin-purelin-purelin	19.379	0.369	0.971	14.070	0.380	0.969
16	purelin-purelin-tansig	23.860	0.420	0.964	0.447	18.180	0.957
17	purelin-purelin-logsig	20.390	0.370	0.972	14.530	0.3768	0.970
18	purelin-tansig-purelin	1.190	0.010	1.000	2.110	0.196	0.992
19	purelin-logsig-purelin	1.170	0.010	1.000	0.180	1.950	0.993
20	tansig-purelin-purelin	1.290	0.010	1.000	2.060	2.060	0.993
21	logsig-purelin-purelin	1.270	0.010	1.000	2.640	0.222	0.990
22	tansig-purelin-logsig	1.480	0.010	1.000	2.310	0.145	0.997
23	**tansig-logsig-purelin**	**1.220**	**0.010**	**1.000**	**0.158**	**1.790**	**0.995**
24	logsig-purelin-tansig	1.640	0.010	1.000	2.870	0.178	0.996
25	purelin-tansig-logsig	1.640	0.010	1.000	44.440	1.290	0.643
26	purelin-logsig-tansig	126.000	1.580	N/A	108.330	1.581	N/A
27	logsig-tansig-purelin	1.350	0.010	1.000	2.340	0.200	0.992

A better view of the results is exhibited in the chart of the correlation between treatments. MAPE and RMSE values were 1.220 and 0.010 in training, respectively, and were 0.158 and 1.790 in testing, respectively. The higher Mean Absolute Percentage Error (MAPE) compared to other activation functions is caused by both internal and external factors. Overfitting results in higher MAPE, especially if the configuration causes the model to focus too much on noise rather than the actual pattern. External factors that can impact the model include image quality and sensor accuracy, which may reduce model accuracy. This highlights that selecting the appropriate activation function can enhance model performance and reduce MAPE (Hwang & Kim, 2023). The coefficients of determination (R^2) are displayed in Figures 9 and 10. The coefficient of regression (R^2) for training was perfect at 1, while that for testing was 0.963, close to 1. It was then concluded that the coefficients of regression for training and testing had good activation functions; hence the chili pepper sorting and grading processes were feasible to be conducted. The results of the process of sorting chili peppers using the conveyor are indicated in Table 5.

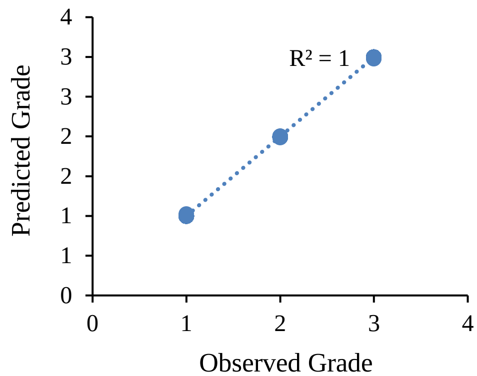

Figure 9. Observation vs Prediction at ANN training

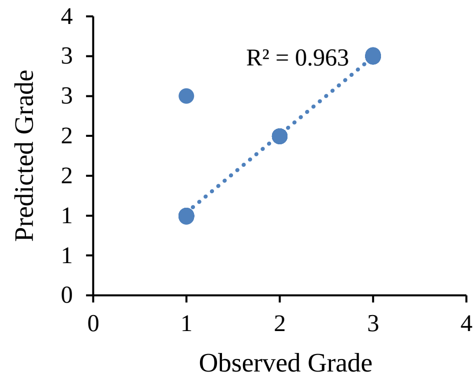

Figure 10. Observation vs Prediction at ANN testing

Table 5. Training and Testing Results

No.	Image	Label	Result	Status
1		Large red	Grade I	Sorter 1, sorter 1, sorter 1
2		Large red	Grade I	Sorter 1, sorter 1, sorter 1
3		Small red	Grade III	Sorter 1, sorter 1, sorter 2
4		Small red	Grade III	Sorter 1, sorter 1, sorter 2
5		Large green	Grade II	Sorter 1, sorter 2, sorter 1
6		Large green	Grade II	Sorter 1, sorter 2, sorter 1
7		Small green	Grade II	Sorter 1, sorter 2, sorter 2
8		Small green	Grade II	Sorter 1, sorter 2, sorter 2
9		Striped	Reject	Sorter 2
10		Striped	Reject	Sorter 2
11		Damaged	Reject	Sorter 2
12		Damaged	Reject	Sorter 2
13		Damaged	Reject	Sorter 2
14		Damaged	Reject	Sorter 2

Process of conversion ANN to Arduino caried out with the following steps. First, Train the ANN model on a computer using Sublime Text with Python, utilizing RGB, HSV, and YCrCb color data as model input. Conduct training and save the weights and biases from each model to be implemented in Arduino. Second, Extract the ANN model parameters by obtaining the trained ANN weights and biases in matrix form for use in Arduino code, using activation functions (tansig, logsig, and purelin). Third, Code the ANN in Arduino IDE in C^{++}, following the previously established architecture. Fourth, Integrate the TCS3200 color sensor and servo with Arduino, providing RGB, HSV, and YCrCb values as input to classify the placement of chili peppers on two servos.

3.3. Electronics Designing

Electronics designing was conducted after image processing and ANN processes were completed, RGB, HSV, YCrCb, and L*a*b values were obtained, and data were input to Arduino Mega to train the TCS230 color sensor. Electronics components were composed of the TCS230 color sensor, Arduino Mega microcontroller, two servo motors, and breadboard connected to the jumper wire.

3.4. Conveyor Application

The conveyor for sorting and grading red chili peppers was 150 cm in length and 15 cm in width (Figure 11). Meanwhile, the sensor bracket was 30 cm long, and the sorters' length was 50 cm. The material was acrylic, printed with a 3D printer, and some were cut using a mini grinder. The belt's material was white food-grade PU. The drive was a DC motor connected to a gearbox using two rollers plus an idler. The belt was speed-adjustable using a potentiometer, helping create no buildup during sorting and grading processes. The conveyor's outputs came only with two criteria adjustable by conditions.

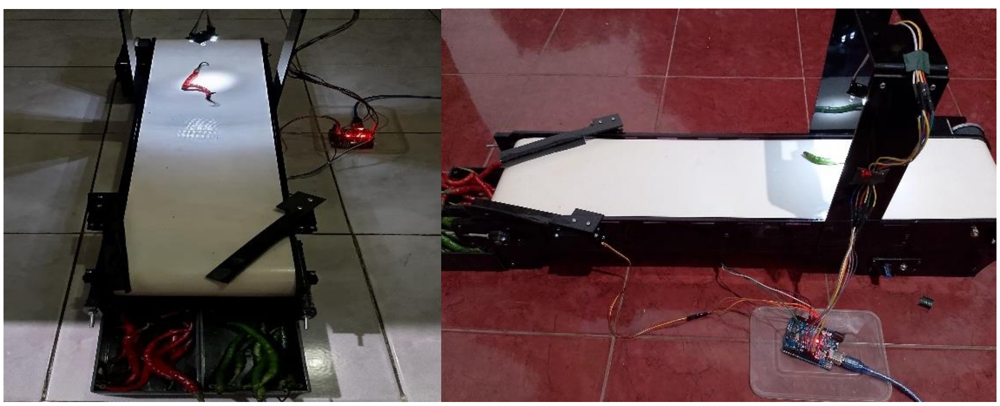

Figure 11. Conveyor sorting for chili pepper

3.5. Sorting and Grading Processes

The sorting process was initiated by sorting all chili peppers mixed and categorizing them into two criteria, i.e., red and green chili peppers were input to sorter 1, while striped or damaged ones were input to sorter 2. Subsequently, chili peppers input to sorter 1 were again sorted to separate red and green ones to go to sorters 1 and 2, respectively. The grading process was performed to separate red chili peppers by size, namely large red chili peppers going to sorter 1 while small ones going to sorter 2. The grading process of green chili peppers was also undertaken using the conveyor, in which large ones were input to sorter 1, while small ones were input to sorter 2. Sorted and graded chili peppers to be sold could be determined for their prices following defined criteria.

The sorting process is done with only 2 servos, selecting only 2 categories for differentiation. However, if all items need to be separated immediately, another conveyor with a different function is required, with 4 categories for the test. The sorting and grading process is based on RGB, HSV, and YCrCb color and size classification, which is then input into ANN programming logic to detect red chili, green chili, and reject items. Once the best program is determined, it is

Table 6. Sorting and grading process of chilies on the conveyor

Test	Status	Servo 1	Servo 2
1	All chilies	Good chili	Reject
2	Good chili	Red chili	Green chili
3	Red chili	Large red chili	Small red chili
4	Green chili	Large green chili	Small green chili

is converted to Arduino as an automatic code to control two servos based on objects detected by the TCS3200 sensor. The conveyor moves continuously, and the servos will activate when the detected object meets the predefined conditions set in the Arduino program.

4. CONCLUSION

The conveyor for automatic sorting and grading was image data-based with RGB values converted into HSV, YCrCb, and L*a*b for color identification and the ROI manager for size classification. The best activation function was tansig-logsig-purelin. The MAPE value was 1.220, RMSE was 0.010, and R^2 was 1 for training, while for testing, MAPE, RMSE, and R^2 values were 0.158, 1.790, and 0.963, respectively. The conveyor was 150 cm in length and 15 cm in width, adjusting to the length of red chili peppers. The produced criteria were grade I (red, 10-15 cm), grade II (green, 10-15 cm), and grade III (red, 5-9.99 cm), while unidentified ones were classified into grade reject. This system can also be applied to other crop commodities where quality and price are determined by color, such as tomatoes, bell peppers, curly chili peppers, bananas, apples, papayas, mangoes, and other types of horticultural products.

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