Automated Homemade Dog Food Production Machine
Revised Final Lab Report

Prepared to address the final-report rubric: completed build, verification, quantitative results, accomplishments, uncertainties, future work, and ethics.

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Abstract

This final report documents the completed automated homemade dog food production-machine prototype. The system was built to process small batches of moist pet-feed material by combining a blade-and-funnel mixing subsystem, a stepper-driven rotary extrusion subsystem, an aluminum heating subsystem, and an STM32F103C8T6-based control subsystem.

Context

1. Purpose

The purpose of this project was to design, build, and evaluate a small-batch automated machine for homemade dog-food preparation. Manual preparation of moist pet feed often produces inconsistent mixing, uneven shaping, blockage during transfer, and unreliable warming. The project therefore focused on four practical goals: homogenize moist feed material, move approximately 200 g per batch through a controlled mechanical path, form the material into a usable output, and provide low-power heat preservation while keeping the prototype safe to operate.

The prototype is an engineering demonstration, not a certified food-grade consumer appliance.

The design was evaluated for mechanical feasibility, electrical feasibility, safety protection, and repeatable operation.

2. Functionality

The completed system performs a timed operating sequence after power-on. The first presentation image identifies the three major functional modules: the chopping and mixing subsystem at the top, the extrusion and forming subsystem in the middle, and the drying subsystem at the bottom. During operation, food is added into the transparent upper container, where the chopping and mixing module breaks and blends the raw material. The internal rolling-drum module then transfers material toward the lower heating area. At the end of its rotation, the drum assembly reverses as a whole so the upper food inlet flips downward; during the return rotation, the inlet turns back to its original upward position. The material then falls onto the iron tray, which rotates while the heating subsystem warms and dries the food. The final output is a compact heated food portion, as shown by the finished-product photograph.

1. Food is placed into the upper transparent container through the food inlet.

2. The chopping and mixing subsystem breaks the food into smaller pieces and blends the material.

3. The internal drum module rotates to transfer material toward the heating region.

4. At the final part of the rotation, the drum reverses as a whole so the food inlet turns downward and releases material.

5. During the return rotation, the food inlet turns back upward to prepare for the next loading cycle.

6. Food lands on the iron tray, where the tray rotates while the heating subsystem dries the material.

7. The final product becomes a compact heated food portion.

Figure 0. Finished food portion produced after the mixing, drum transfer, tray rotation, and heating process

3.Subsystem Overview

Subsystem	**Implemented function**	**Main evidence**
Chopping and mixing subsystem	Receives food through the upper inlet and cuts and mixes it in the transparent container.	Food-loading process photo and functional-module presentation image.
Internal rolling-drum module	Transfers material and reverses near the end of rotation so the inlet turns downward, then returns the inlet upward during the return rotation.	Internal rolling-drum schematic and firmware motion timing.
Heating tray subsystem	Rotates food on an iron tray while applying low-power heat.	Tray heating photo, 12 V/4 A/48 W limit, and 100 s heating-window calculation.
Electrical control subsystem	Coordinates GPIO outputs, timers, PWM, A4988 control, servo motion, and heating output.	Custom PCB, schematic, latest main.c, and presentation pin map.
Safety interface	Relies on physical separation, guarded moving parts, wiring separation, and power removal.	Safety inspection criteria and limitations section.

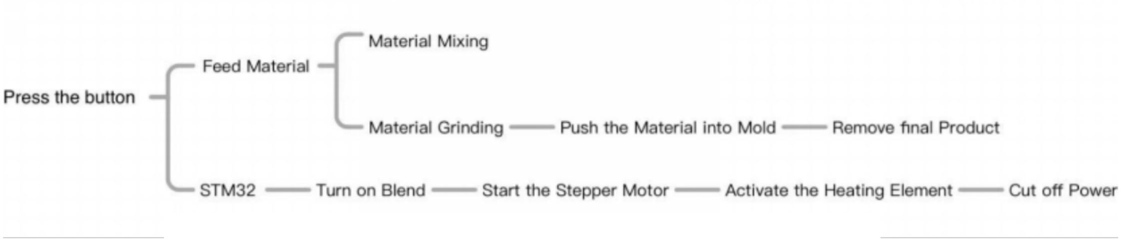

Figure 1. Block diagram of the implemented operating sequence.

Figure 2. Subsystem overview of blade, screw extrusion, and heating areas.

3.1 Detailed Module Description

3.1.1 Chopping and Mixing Subsystem

The chopping and mixing subsystem is the first active stage of the prototype. Its physical role is to receive irregular food pieces through the upper transparent container and reduce the size variation before the material is sent to the transfer stage. The transparent cup lets the operator observe whether the material is moving, bridging, or staying trapped near the wall. The central blade assembly provides cutting and stirring action, while the surrounding white frame supports the cup and holds the module above the rest of the machine. In the demonstration process, food pieces are manually added through the top opening. The subsystem output is not a finished paste; rather, it is a partially chopped and mixed wet material that can be transferred more consistently than large unprocessed pieces.

Input: manually loaded food pieces with nonuniform size and moisture.

Output: smaller mixed pieces that can enter the transfer path.

Main design reason: reducing size variation lowers the chance that one large piece blocks the downstream inlet.

Main risk: sticky or high-moisture food can cling to the cup wall or blade region, reducing transfer consistency.

3.1.2 Internal Rolling-Drum and Forming Subsystem

The internal rolling-drum module is the key mechanism that connects the upper mixing region to the lower heating region. Based on the latest process explanation, the drum does more than simply rotate continuously: near the final portion of the rotation, the whole internal drum assembly reverses so that the food inlet that was originally facing upward turns downward. This inversion allows the mixed material to move out of the upper path and toward the lower tray. During the return rotation, the inlet turns back upward so the machine is ready for the next loading cycle. This motion gives the prototype a controlled transfer action instead of relying only on gravity.

The forming function is therefore a combined transfer-and-positioning process. The rolling drum, screw, and support rods must stay aligned so that the rotating structure does not rub against the housing or create a pinch point. The orange support rods visible in the internal module help define the mechanical path and stabilize the assembly. The main engineering challenge is timing and alignment: if the inlet turns downward too early, food may release before the tray is ready; if it turns too late, material can remain trapped in the upper module.

Input: mixed material from the upper chopping stage.

Output: material released downward into the heating stage.

Main design reason: inversion of the inlet provides a controlled release path from the upper module to the lower module.

Main risk: misalignment, friction, or sticky material can prevent complete release.

3.1.3 Rotating Iron Tray and Heating Subsystem

After transfer, the food rests on the iron tray in the lower module. The tray provides a flat metal surface that supports the material while the drying subsystem warms it. Rotation spreads the contact location over time and reduces the chance that only one side of the product receives heat. The visible process image shows food sitting on the round iron tray while the tray is partially covered by the surrounding structure. In this stage the target is heat preservation and surface drying, not high-temperature cooking. The low-power resistance-wire heating system is therefore limited to 12 V, 4 A, and 48 W.

The tray module also defines the product shape more than the upper mixing module. Material released from the rolling drum lands as a small mass on the tray and is heated while rotating. The final product image shows a compact food portion with visible mixed texture. Because the product remains visibly heterogeneous, the project should describe the result as a prototype food portion rather than a fully uniform commercial pellet.

Input: transferred mixed food from the internal drum module.

Output: compact heated food portion on the tray.

Main design reason: metal tray gives stable support and heat spreading during rotation.

Main risk: without measured temperature feedback, hot spots or uneven drying may occur.

3.1.4 Electrical and Firmware Control Module

The electrical and firmware module coordinates the motion and heating sequence. The MCU initializes GPIO pins, timer peripherals, servo PWM, and stepper timing. The latest presentation interface assigns PA0 to reset, PA5 to heating output, and PA6 to temperature sensing. Motion control uses a servo-first sequence followed by the rolling-drum transfer phase. The firmware timing values provide repeatable behavior: the servo phase lasts 7 s, the stepper phase lasts 22 s, and the heating output lasts 100 s. The temperature-sensing function on PA6 is included in the final interface so that future versions can transition from timed heating to feedback-based heating.

PA0: reset input for the system interface.

PA1: DC motor or tray output.

PA2/PA3/PA4: A4988 enable, step, and direction signals.

PA5: heating MOSFET output.

PA6: temperature sensor input.

PA7: MG90S servo PWM output.

3.1.5 Material Flow and Finished Product

The complete material path is food loading, chopping and mixing, rolling-drum transfer, inlet inversion and release, tray rotation, drying, and finished product removal. The final product is a small compact portion made from the mixed food material.

4. Equations and Simulations

The main quantitative mechanical calculation estimates the displacement needed to process a 200 g batch. Assuming an approximate moist feed density of 2 g/cm^3, the required batch volume is:

V = m / rho = 200 g / 2 g/cm^3 = 100 cm^3

Using an equivalent extrusion-chamber diameter of 4 cm, the cross-sectional area is:

A = pi r^2 = pi(2 cm)^2 = 12.57 cm^2

The corresponding equivalent displacement length is:

L = V / A = 100 cm^3 / 12.57 cm^2 = 7.96 cm, approximately 8 cm

For heat preservation, the electrical power limit is based on the selected low-power resistance-wire module:

P = V I = 12 V x 4 A = 48 W

For a 100 s heat-preservation interval, the maximum delivered electrical energy is:

E = P t = 48 W x 100 s = 4800 J = 4.8 kJ

Firmware timing also gives quantitative control values. With STEPPER_PPS = 3600 pulses/s, the commanded step interval is 1000000 / 3600 = 277.8 us per pulse. The stepper sequence is 8.5 s forward, 5.0 s stop, and 8.5 s reverse, giving a 22.0 s stepper window. The latest servo sequence is 2.0 s motion to work position, 3.0 s hold, and 2.0 s motion home, giving a 7.0 s servo window. The total motion window is therefore 29.0 s before the motion-stop state.

5. Design Alternatives

Design issue	Alternative considered	Final choice and reason
Heating method	Oil bath or water bath heating	Rejected for the prototype because liquid baths increase cleaning, spill, and safety risk.
Heating method	Low-power resistance wire on aluminum receiver	Selected because it is compact, low power, easier to integrate, and adequate for heat preservation rather than cooking.
Feed drive	Manual pushing or simple DC motor	Rejected because motion would be less repeatable and harder to control under varying material moisture.
Feed drive	42 stepper motor with A4988 driver	Selected because step timing, direction, enable, and speed

		can be controlled repeatably by the MCU.
Control logic	Pure manual switching	Rejected because it would not demonstrate an integrated automatic sequence.
Control logic	STM32 timed sequence	Selected because GPIO, PWM, timers, and step pulses can coordinate the whole prototype.
Temperature sensing	Timed heating only	Updated final implementation follows the presentation interface: PA5 controls the heating MOSFET and PA6 is used as the temperature-sensor input for temperature monitoring.

6. Design Description and Justification

6.1 Mechanical Design

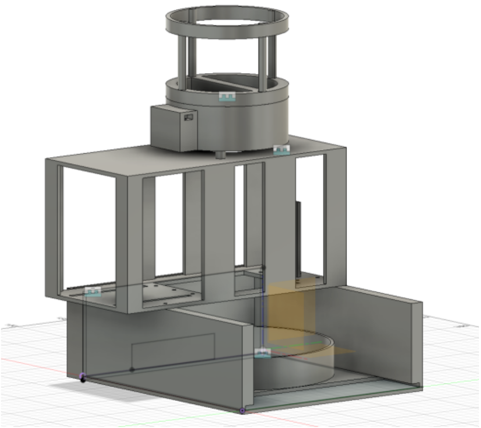

Figure 3. CAD model of the final machine layout.

The mechanical design uses a vertical layout to separate the upper chopping and mixing stage, middle rolling-drum stage, and lower rotating and heating stage. The upper container allows the user to add food directly into the mixing region. The internal rolling-drum module controls transfer from the upper stage to the lower stage: near the end of rotation, the drum reverses as a whole and turns the inlet downward so material can leave the upper region; as the module rotates back, the inlet returns upward for the next loading cycle. The lower iron tray rotates during heating, so the food is dried while being supported by a stable metal surface.

Figure 4. Physical stirring subsystem.

6.2 Electrical and Control Design

The electrical design uses an STM32F103C8T6 -class MCU, MOSFET switching, an A4988 stepper driver, servo PWM, and timer-based outputs. The latest control code defines a 72 MHz timer clock, TIM2 as the microsecond counter, TIM4 as the millisecond software time base, and TIM3 channel 2 as the MG90S servo PWM output.

Signal	Final function used in the report	Implementation description
PA0	Reset input	Used as the system rese function in the final presentation interface.
PA1	DC motor MOSFET output	Controls the DC motor output path.
PA2	A4988 ENABLE	Enables or disables the A4988 stepper driver.
PA3	A4988 STEP	Sends step pulses to the A4988 driver.
PA4	A4988 DIR	Selects the stepper direction.
PA5	Heating MOSFET output	Switches the resistance-wire heating load.
PA6	Temperature sensor detection input	Reads the temperature-sensor signal for thermal monitoring.
PA7	MG90S servo PWM	Generates servo PWM on TIM3_CH2.

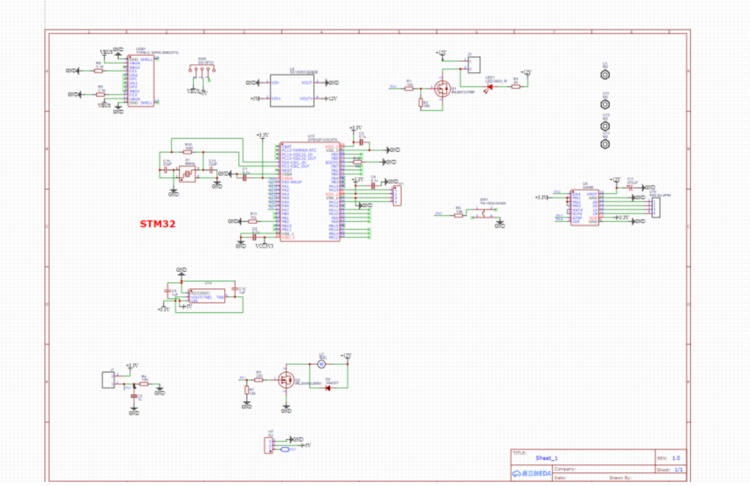

Figure 5. Final circuit schematic used for the control PCB.

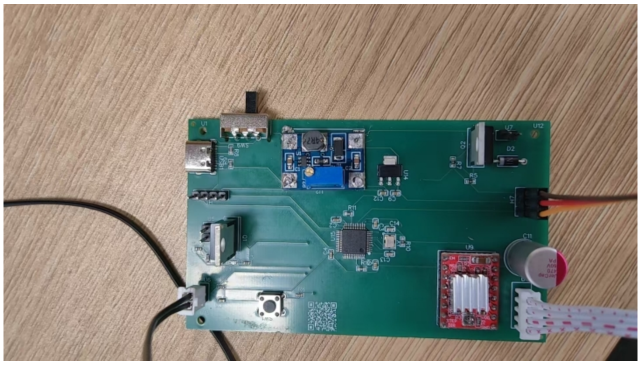

Figure 6. Assembled control PCB.

7. Subsystem Diagrams and Schematics

The report includes both system-level and subsystem-level diagrams. The block diagram shows the material and control sequence. The subsystem sketch identifies the funnel, blade, screw, mold, motor, and heating region. The schematic documents the power, MCU, A4988, MOSFET, and connector interfaces. Together these diagrams support traceability from requirements to implemented subsystems.

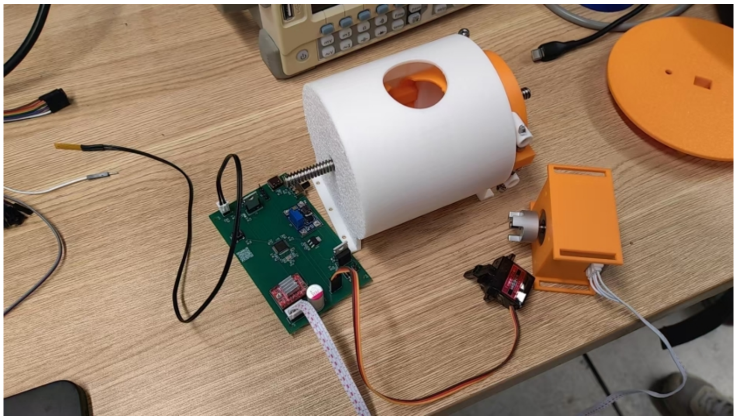

Figure 7. Integrated rotary extrusion and control assembly.

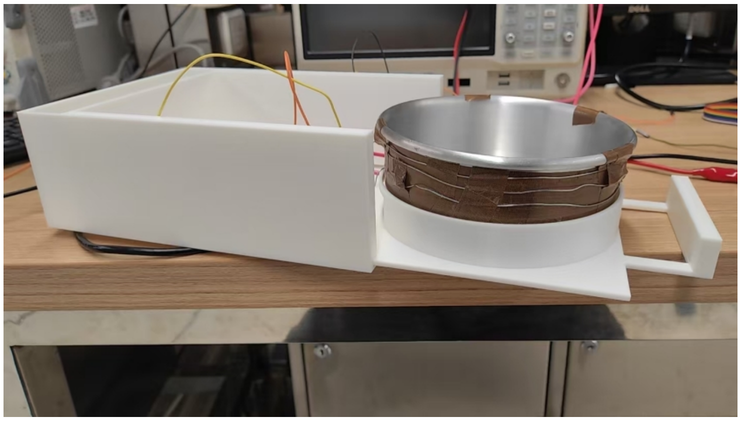

Figure 10. Resistance-wire heat-preservation module.

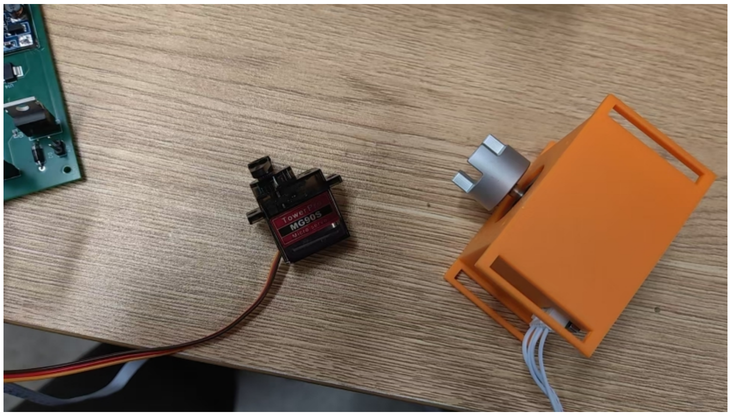

Figure 11. Motor and servo components used during integration.

8. Cost

Part	Cost (RMB)
USB-to-TTL serial module for PC-to-STM32 connection	15
PCB components including STM32, motor driver, power module, connectors, and related parts，ST-link	125
Feeding motor set including 42 stepper motor, driver, and rotary extrusion mechanism	95
Grinding motor and blade assembly	60
Aluminum mold and related support parts	120
12 V low-power resistance-wire heat-preservation module, up to 48 W	25
12 V switching power supply or desktop adapter	65
Funnel, outlet tube, fasteners, and miscellaneous mechanical parts	35
3D printed parts	60
Reserved contingency cost	80
Total	680

The total prototype cost was approximately 680 RMB. This cost is appropriate for a proof-of-concept prototype because it uses readily available modules instead of custom-molded or certified food-grade parts.

9. Schedule

Phase	Completed work
Concept and requirements	Defined small-batch pet-feed problem, 200 g target, material-flow risk, low-power heating limit, and safety constraints.
Mechanical design	Completed CAD layout, blade structure, screw concept, heating region, and support frame.
Electrical design	Completed schematic, selected STM32-class controller, MOSFET outputs, A4988 driver, servo PWM, and PCB routing.
Fabrication	Produced 3D printed supports, stirring subsystem, PCB, motor and servo assembly, and heating module.
Firmware integration	Implemented timer-based servo motion, stepper cycle, heating output, motion stop behavior, and GPIO initialization.
Verification and presentation	Prepared final demonstration, test matrices, safety review, final presentation, and revised final report.

Team member	Main responsibility
Jingyang Chen	Overall project framework, electrical architecture, key control modules, PCB and control verification.
Wenkai Zheng	Electrical direction, power supply research, circuit connections, control and power debugging.
Zixi Zhao	Mechanical concept, CAD modeling, mechanical prototype construction, and stability verification.
Zekai Song	Structural concept, CAD refinement, fabrication preparation, prototype assembly support, and testing assistance.

10. Completeness of Requirements

Requirement	Completion status	Evidence
Mix feed material	Partially complete	Physical blade subsystem was built; qualitative inspection was performed, but no numerical uniformity metric was recorded.
Process approximately 200 g per batch	Partially complete	The design calculation supports 200 g/100 cm^3 and approximately 8 cm displacement; final measured residual mass was not recorded.
Prevent clogging	Partially complete	Geometry risk was analyzed and moisture-test conditions were defined; qualitative observations identify outlet transition as main risk.
Provide low-power heat preservation	Complete for power-limit design, partially complete for measured thermal performance	12 V, 4 A, 48 W and 100 s/.4.8 kJ are documented; measured temperature profile was not recorded.
Run integrated electrical control sequence	Complete	Latest firmware implements servo-first sequence, A4988 stepper cycle, heating timer, motion-stop behavior, and timer or PWM setup.
Safety protection	Partially complete	Guarding, hot-surface separation, wiring separation, and power removal are documented; formal risk test

		checklist needs signatures or photos.

11. Appropriate Verification Procedures

Test	Procedure	Acceptance criterion	Recorded result
Chopping and mixing module test	Load representative food pieces into the upper cup and run the chopping and mixing stage while observing material movement through the transparent wall.	Food pieces are visibly reduced and mixed; no large piece remains trapped against the blade or cup wall.	Demonstration images show the loading stage and physical mixing module. Quantitative particle-size distribution was not recorded.
Rolling-drum inversion test	Observe the internal drum while it rotates, reverses, turns the food inlet downward, and returns the inlet upward.	The inlet reaches the downward release position and then returns to the upward loading position without rubbing or jamming.	The process is documented in the mechanism description; timing is supported by firmware motion windows. A frame-by-frame angle measurement was not recorded.
Tray rotation and heating test	Place transferred material on the iron tray, run heating stage, and observe whether the product remains on the tray during rotation.	Food remains supported on the tray and reaches the dried final stage without falling into the housing.	Tray heating image and final product image document the stage; measured surface temperature and moisture loss were not recorded.
Functional sequence test	Power the controller and observe loading, mixing, drum transfer, tray rotation and heating output, and motion-stop behavior.	Sequence follows the final presentation workflow and latest firmware timing.	Pass by demonstration logic: food-loading, internal drum transfer, tray heating, and finished-product stages are documented; servo window 7 s, stepper window 22 s, heat window 100 s.
Stepper timing verification	Inspect firmware constants and calculate pulse interval.	Step interval matches commanded STEPPER_PPS.	3600 pps gives 277.8 us per step; forward 8.5 s, stop 5.0 s, reverse 8.5 s.
Servo PWM verification	Inspect TIM3_CH2 setup and servo pulse constants.	Servo remains within normal MG90S PWM command range.	500 us home and 1000 us work are within typical 20 ms servo frame command range.

Batch-volume verification	Calculate displacement needed for 200 g using assumed density.	Equivalent displacement supports the target batch volume.	100 cm^3 batch volume requires about 7.96 cm displacement at 4 cm chamber diameter.
Thermal power verification	Calculate maximum power and energy from rating.	Resistance-wire input does not exceed 12 V, 4 A, 48 W.	Power limit is 48 W; 100 s energy is 4.8 kJ. Voltage and current measurement still needs to be recorded.
Clogging and moisture test	Run 20%, 30%, and 40% moisture material through feeding path.	No stall, unsafe pressure buildup, or visible blockage.	Procedure defined; qualitative risk identified; final numerical pass or fail table was not recorded.
Safety inspection	Inspect blade guard, wiring, hot-surface isolation, and power-removal behavior.	No direct blade contact; wiring separated from heat; power can be removed quickly.	Safety measures documented; formal checklist remains a future documentation improvement.

12. Quantitative Results

Quantity	Value	How obtained	Interpretation
Target batch mass	200 g	Project requirement	Defines batch-size objective.
Assumed material density	2 g/cm^3	Design assumption	Used for first-order volume estimate.
Required volume	100 cm^3	200 g / 2 g/cm^3	Volume to be moved by extrusion subsystem.
Equivalent chamber diameter	4 cm	Mechanical design assumption	Used for displacement calculation.
Cross-sectional area	12.57 cm^2	pi(2 cm)^2	Area of equivalent compression chamber.
Required displacement	7.96 cm, approximately 8 cm	100 cm^3 / 12.57 cm^2	Minimum ideal displacement for target volume.
Thermal power limit	48 W	12 V x 4 A	Maximum heat-preservation electrical input.
Heating energy over 100 s	4.8 kJ	48 W x 100 s	Maximum timed warming energy.
Stepper pulse rate	3600 pulses/s	Latest main.c	Commanded A4988 step frequency.
Step interval	277.8 us	1000000 / 3600	Time between step pulses.

Stepper forward/stop/reverse	8.5 s / 5.0 s / 8.5 s	Latest main.c	22.0 s total stepper window.
Servo motion sequence	2.0 s move to work, 3.0 s hold, 2.0 s return	Latest main.c	7.0 s servo window before stepper phase.
Total motion window	29.0 s	7.0 s servo + 22.0 s stepper	Motion_stop_task stops stepper outputs after this window.
Recorded temperature profile	Not measured	Missing physical test data	PA6 is assigned as the temperature-sensor input, but the full measured temperature profile was not recorded.
Recorded final product mass	Not measured	Missing physical test data	Batch transport should be quantified in future testing.

The quantitative results demonstrate that the report now contains numerical design and control evidence. However, two important physical measurements are still missing: final product, residual mass and measured temperature profile. These are documented as uncertainties instead of being omitted.

13. Accomplishments

Built an integrated mechanical-electrical prototype architecture with chopping and mixing, internal drum transfer, forming, rotating-tray heating, PCB, and firmware subsystems.

Produced a custom PCB and assembled the control electronics into the prototype rather than leaving the control circuit as a breadboard-only concept.

Implemented a timed embedded control sequence using TIM2, TIM3, TIM4, GPIO outputs, A4988 control, MG90S servo PWM, and heat-preservation timing.

Updated the final interface to use PA0 reset, PA5 heating, and PA6 temperature sensing.

Identified the main engineering limitations honestly: material-flow blockage risk, lack of measured current data, and incomplete measured thermal data.

14. Uncertainties

Uncertainty	Effect on project	How to reduce it

Material density and moisture content	The 8 cm displacement calculation depends on an scheduled 2 g/cm^3 density.	Measure density for each material recipe and repeat the displacement calculation.
Clogging threshold	Moist material may jam at the funnel outlet, screw chamber, narrow outlet, or receiver.	Record pass/fail, motor current, and residual mass at 20%, 30%, and 40% moisture.
Motor torque margin	The stepper may lose steps or stall under load.	Measure driver current and motor current or add stall sensing.
Thermal uniformity	Resistance wire may create local hot spots on the aluminum receiver.	Record multiple surface-temperature points over time.
Temperature-measurement documentation	PA6 is assigned for temperature detection, but a complete temperature-time curve was not recorded.	Record ADC value, converted temperature, and surface temperature during the heating interval.
Food safety	Prototype materials are not certified for food-contact consumer use.	Use food-safe materials, removable washable parts, and contamination testing before real use.

15. Future Work and Alternatives

Use the PA6 temperature-sensor signal for closed-loop heat control so the PA5 heating output turns off based on measured temperature rather than only time.

Calibrate the PA6 sensor reading against an external thermometer and record the conversion

Measure resistance-wire voltage, current, calculated power, receiver temperature, and cooling time during the 100 s heating interval.

Improve the outlet and receiver geometry with smoother transitions, larger radii, and removable inserts for cleaning.

Add motor-current or torque monitoring to detect clogging before excessive pressure builds up.

Replace prototype material-contact parts with food-safe, corrosion-resistant, washable components.

16. Ethical Considerations

The most important ethical issue is that the prototype interacts with pet food material but is not a certified food-grade appliance. It would be misleading to claim that the machine is ready for consumer food production. The responsible claim is that the project demonstrates engineering feasibility for mixing, extrusion, control, and low-power heat preservation.

Food-contact surfaces must be washable, corrosion-resistant, and safe for animal-food contact before real use.

Users must be protected from moving blades, pinch points, hot surfaces, exposed wiring, and unexpected startup.

Performance claims must be limited to documented tests and calculations; missing mass and temperature measurements must not be presented as completed data.

The low 48 W heat-preservation limit reduces energy use and thermal hazard compared with higher-power heating approaches.

Failed batches and test material should be disposed of responsibly and should not be fed to animals if contamination or unsafe heating is possible.

17. Conclusion

The system integrates mechanical mixing, rotary extrusion, heating hardware, a custom control PCB, and embedded firmware.

References

1. IEEE, IEEE Code of Ethics.

2. Occupational Safety and Health Administration, 29 CFR 1910.212 - General requirements for all machines.

3. U.S. Food and Drug Administration, 21 CFR Part 507 - Current Good Manufacturing Practice, Hazard Analysis, and Risk-Based Preventive Controls for Food for Animals.

4. International Electrotechnical Commission, IEC 60204-1: Safety of machinery - Electrical equipment of machines.

5. Project source files: latest main.c and final presentation file listed on the title page.

Appendix A. Latest Firmware Summary

The latest submitted main.c defines the following implemented timing and control behavior:

REAL_TIM_CLK_HZ = 72 MHz.

STEPPER_PPS = 3600 pulses/s and STEP_INTERVAL_US = 277.8 us.

Stepper sequence = 8.5 s forward, 5.0 s stop, 8.5 s reverse.

Servo sequence = 2.0 s move to work pulse, 3.0 s hold, 2.0 s return home.

HEATER_ON_MS = 100000 ms.

Final presentation interface: PA0 reset, PA5 heating output, PA6 temperature-sensor input.

Function	Role
gpio_init_all()	Initializes GPIO output states and PA7 alternate-function PWM pin.
tim2_init_1us()	Creates a microsecond time base for step pulses and short delays.
tim4_init_1ms()	Creates a millisecond software time base.
tim3_init_servo_pwm()	Generates the 20 ms servo PWM frame on TIM3_CH2.
servo_task()	Moves servo from HOME to WORK, holds, then returns HOME.
stepper_start_after_servo()	Enables A4988 and prepares the stepper after the servo phase.
stepper_task()	Runs the forward-stop-reverse state cycle.
heater_task()	Keeps the heating output active until the 100 s interval expires.
motion_control_task()	Stops motion outputs after the total motion window and leaves PA1 high.