

Automated Homemade Dog Food Production Machine

Group 33

Zekai Song, Zixi Zhao, Wenkai Zheng, Jingyang Chen

I. Introduction

Currently, many people are choosing to raise a dog for company. However, dog foods are relatively expensive, while the raw materials for it are quite cheap. This leads to the possible solution – to make dog food at home. However, producing small batches of pet feed from moist raw material is difficult because the material must be mixed uniformly, transported without clogging, and dried to a stable moisture level for storage. Conventional manual processing is inefficient and inconsistent, especially when the material moisture content varies.

To address this problem, our team designed an automated homemade dog food production machine that integrates a blade mixing subsystem, a stepper-motor-driven feeding subsystem, and a thermal drying and molding subsystem, all coordinated by an electrical control system. The machine is intended to process approximately 200 g of material per batch, shape the material through a mold, and reduce its moisture content to a level suitable for storage.

The design is guided by three high-level requirements:

The system shall maintain stable material flow without clogging during feeding and molding.

The system shall process approximately 200 g of material per batch in a controlled and repeatable manner.

The system shall reduce the final moisture content to approximately 15% within 30 minutes while maintaining safe and practical operation.

Figure 1 illustrates the overall concept and how the final system is used in the context of pet feed production.



Figure 1: Pictorial Representation of How the Machine is used in Real Life Context

II. Design

2.1 Block Diagram

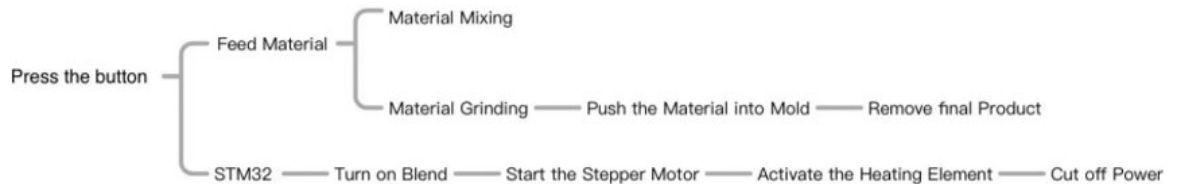


Figure 2: Block Diagram

2.2 Subsystems

2.2.1 The Subsystems Overview

The system consists of three main mechanical subsystems and an electrical control subsystem. The overall process is continuous and controlled through coordinated interactions between mechanical components and the control system.

Feed material is manually loaded into a funnel. At the bottom of the funnel, rotating blades cut and blend the material to achieve a uniform mixture. Under the regulation of the electrical control system, the processed material is then delivered at a controlled rate into the second subsystem, the material feeding system.

The feeding system consists of a stepper motor, a screw, and a piston. Driven by the stepper motor and regulated by the control system, the material is conveyed and compressed forward into the thermal drying and molding subsystem.

This final subsystem includes an openable aluminum mold and electrically controlled heating wires. The working principle is similar to injection molding: the material is pushed into the mold by the feeding system, and then heated to remove moisture and solidify the product, making it suitable for storage.

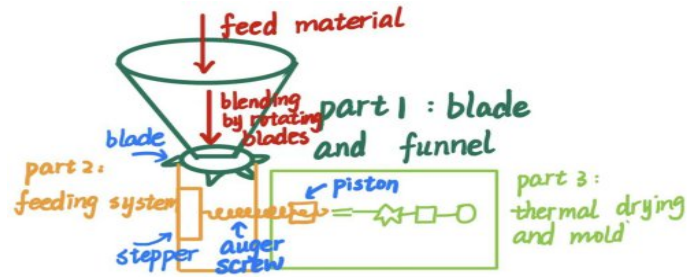


Figure 3: Subsystems Overview

2.2.2 Subsystem 1: Blade and Funnel System

This subsystem is a simple mechanical system designed to grind and homogenize the input material, ensuring a uniform mixture for subsequent processing.

Table 1: Blade and Funnel System

Requirements	Verification
The system shall grind the feed material effectively without clogging or blockage.	The system performance will be evaluated through visual inspection. Feed materials with different moisture contents will be tested to determine whether they affect system operation or cause blockage.

All components are commercially available and the programming is simple, as only the blade speed needs to be controlled; therefore, the feasibility analysis is omitted.

2.2.3 Subsystem 2: Feeding System

The system drives a piston to push the material forward by rotating a screw connected to a stepper motor. A schematic of the final product is shown in the figure. The key challenge is to use an STM32-based control system to effectively regulate the speed and torque output of the stepper motor.

Based on the current design, each batch processes approximately 200 grams of material.

Assuming a density of 2 grams per cubic centimeter, the required volume is

100 cubic centimeters. With a piston diameter of 4 centimeters, the corresponding effective stroke length is approximately 8 centimeters.

However, the material is subsequently pushed into a narrow tube with a diameter of 1 centimeter connected to the mold. To prevent clogging and ensure stable operation, precise control of the stepper motor speed using the STM32 is critical. Proper speed regulation ensures sufficient driving force while avoiding excessive resistance buildup in the narrow channel.

Table 2: Feeding System

Requirements	Verification
Control the speed and force to prevent clogging. Test the system performance with feed materials containing 20%, 30%, and 40% moisture content.	Various combinations of feed composition and piston diameter will be evaluated. In the event of clogging, the piston diameter will be reduced while increasing the effective stroke length of the stepper-driven mechanism to improve flow and prevent blockage. And select the lowest possible moisture content that does not cause clogging in order to minimize the drying time.

The stepper motor is a well-established and mature technology, with extensive documentation and learning resources available online. Our team will follow an STM32-based stepper motor control tutorial to develop and implement the control system [1]. In addition, a custom-designed piston will be used to meet the specific requirements of the system.

The specifications of the selected stepper motor are provided below. Its load capacity is sufficient to support the required operating conditions of the system.

Table 3: Stepper Motor Specifications [2]

定格特性 RATED CHARACTERISTICS	
相数 PHASES	2
基本ステップ角度 FUNDAMENTAL STEP ANGLE	1.8 °
定格電圧 RATED VOLTAGE	2.88 V [DC]
定格電流 RATED CURRENT	1.2 A/PHASE
巻線抵抗 WINDING RESISTANCE	2.4 Ω±10% at 25 °C
巻線インダクタンス WINDING INDUCTANCE	2.3 mH±20% at 1 kHz 1 V [rms]
ホールディングトルク HOLDING TORQUE	0.2 N·m MIN. at I=1.2 A/PHASE 2 PHASE EXCITATION.
脱出トルク NOTE1 PULL-OUT TORQUE	0.15 N·m MIN. at 1000 pulse/s
	負荷イナーシャ INERTIAL LOAD 0.94×10 ⁻⁴ kg·m ² (ラバーカップリングイナーシャを含む) (INERTIA OF RUBBER COUPLING IS INCLUDED)
最大自起動周波数 NOTE1 MAXIMUM STARTING PULSE RATE	1600 pulse/s MIN. at NO LOAD
最大連続応答周波数 NOTE1 MAXIMUM SLEWING PULSE RATE	3400 pulse/s MIN. at NO LOAD
静止角度誤差 POSITIONAL ACCURACY	±0.09 ° (0.18 °SPREAD MAX.) 2 PHASE EXCITATION.
温度上昇値 NOTE2 TEMPERATURE RISE	80 K MAX.
ローターイナーシャ ROTOR INERTIA	0.036×10 ⁻⁴ kg·m ² NOMINAL
耐熱クラス THERMAL CLASS	B
許容スラスト荷重 ALLOWABLE THRUST LOAD	10 N
許容ラジアル荷重 ALLOWABLE RADIAL LOAD	26 N 軸先端荷重 LOAD TO SHAFT END.

2.2.4 Subsystem 3: Thermal Drying and Mold System

The core of this subsystem is low-temperature drying. An openable aluminum mold and electrically controlled heating elements are used to complete this process. The system is designed to operate at a temperature below 60 degrees Celsius for approximately 30 minutes, reducing the moisture content of the material to around 15% for improved storage stability.

Due to the use of low-temperature drying, excessive dehydration of the material is unlikely. The overall mold design is similar to an injection molding process, where the material is distributed through small internal channels to multiple mold cavities. The total mass processed in a single drying cycle is approximately 200 grams.

Table 4: Thermal Drying and Mold System

Requirements	Verification
The drying temperature and duration shall be controlled to achieve a final moisture content of approximately 15%, with a processing time not exceeding 30 minutes.	A parametric study will be performed using feed materials with initial moisture contents of 25%, 30%, and 35%. Drying will be conducted at 50, 60, and 70 degrees Celsius for 20 and 30 minutes to identify the optimal temperature–time combination for each condition.

The core objective of this subsystem is to ensure uniform heating. To achieve more precise and intelligent control, a DHT111 temperature and humidity sensor will be integrated for real-time temperature monitoring.

In addition, the sensor provides humidity measurements, which can be used to assess the drying condition of the material and support more accurate process control.

Table 5: DHT111 Specifications [3]

5.1 相对湿度

表 1 相对湿度性能表

参数	条件	min	type	max	单位
量程范围		5		95	%RH
精度 ^[1]	25°C		± 5		%RH
重复性			± 1		%RH
互换性		完全互换			
响应时间 ^[2]	1/e(63%)		<6		S
迟滞			± 0.3		%RH
漂移 ^[3]	典型值		< ± 0.5		%RH/年

5.2 温度

表 2 温度性能表

参数	条件	min	type	max	单位
量程范围		-20		60	°C
精度 ^[1]	25°C		± 2		°C
重复性			± 1		°C
互换性		完全互换			
响应时间 ^[2]	1/e(63%)		<10		S
迟滞			± 0.3		°C
漂移 ^[3]	典型值		< ± 0.5		°C/年

5.3 电气特性

表 2 电气特性

参数	条件	min	type	max	单位
供电电压		3.3	5.0	5.5	V
供电电流		0.06(待机)	-	1.0(测量)	mA
采样周期	测量		>2		S/次

[1] 此精度为出厂时检验时，传感器在 25°C 和 5V，条件下测试的精度指标，其不包括迟滞和非线性，且只适合非冷凝环境。

[2] 在 25°C 和 1m/s 气流的条件下，达到一阶响应 63% 所需要的时间。

[3] 在挥发性有机混合物中数值可能会高一些。见说明书应用储存信息。

The specifications of the DHT111 sensor are provided below and are sufficient for this application. Due to its temperature limitations, it will not be used at 70 degrees Celsius, but will assist in monitoring and control under lower temperature conditions

2.3 Electrical Control System

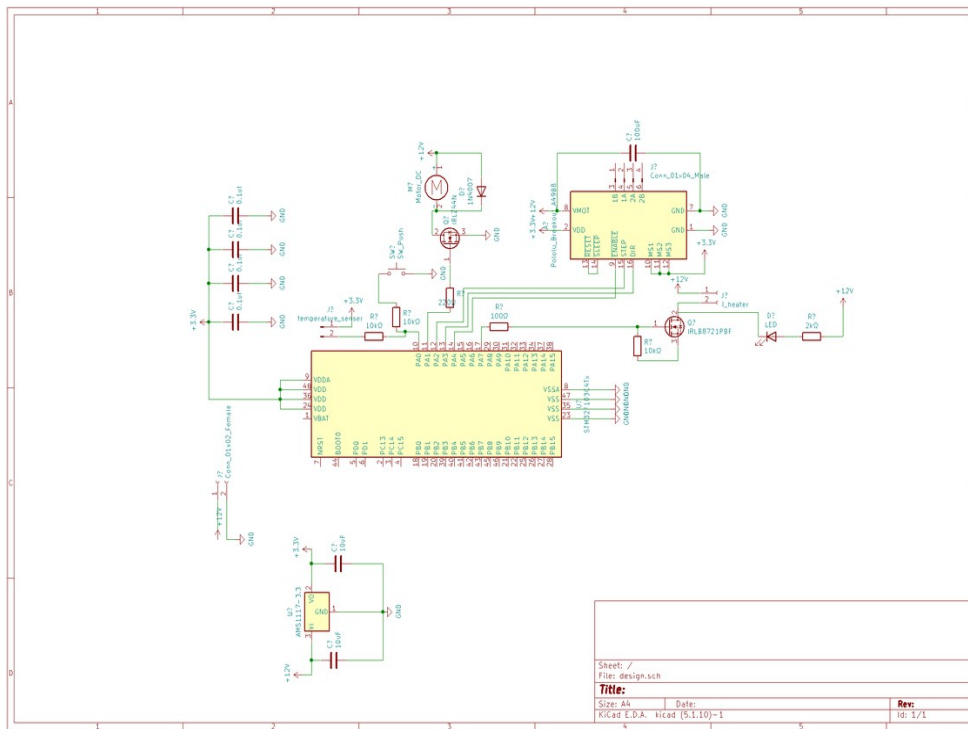


Figure 6: Electrical Control System

2.4 Tolerance Analysis

The most critical part of this system is the material feeding and low-temperature drying subsystem, which determines whether the material can be transported smoothly and dried to a suitable moisture content. Failure in this subsystem may lead to clogging or insufficient drying.

2.4.1 Design-Level Risks

(a) Material Flow Stability:

Material moisture content and composition affect flow behavior and may cause clogging.

(b) Stepper Motor Control:

Motor speed must be regulated to provide sufficient driving force while avoiding excessive pressure.

(c) Geometric Matching:

The piston diameter and outlet tube must be properly matched to ensure stable feeding.

(d) Heating Uniformity:

Non-uniform heating may result in uneven drying.

2.4.2 Feeding Calculation

For a batch of 200 grams and a density of 2 grams per cubic centimeter, the required volume is:

$$V = 200 / 2 = 100 \text{ cubic centimeters}$$

For a piston with a diameter of 4 centimeters, the cross-sectional area is:

$$A \approx 12.57 \text{ square centimeters}$$
 Thus,

the required piston stroke is:

$$L = V / A \approx 100 / 12.57 \approx 8 \text{ centimeters}$$

This provides sufficient displacement, but additional resistance from the 1-centimeter outlet tube requires careful motor control.

2.4.3 Drying Requirement

The system aims to reduce the moisture content to approximately 15% within 30 minutes at temperatures below 60°C, while avoiding excessive dehydration.

2.4.4 Verification

Tests will be conducted using materials with different moisture contents (20–40%) and drying conditions (50–70°C, 20–30 minutes).

Successful operation is defined as:

- no clogging
- stable material flow
- final moisture \approx 15%
- drying time \leq 30 minutes

2.4.5 Conclusion

The main uncertainties lie in material flow and drying performance. With proper control of motor speed and drying parameters, the system is expected to meet the design requirements

III. Cost Evaluation

The projected cost of the prototype is summarized in Table 6. The estimate includes the major mechanical, thermal, sensing, and control components required to implement the blade and funnel system, feeding subsystem, low-temperature drying subsystem, and electrical control subsystem. Small consumables and fabrication losses are included in the contingency budget.

Table 6: Cost Evaluation

Part	Cost (rmb)
USB-to-TTL Serial Module (connect PC to STM32)	15
All PCB components (STM32, motor driver, power module, connectors and others)	85
Feeding motor set (42 stepper motor + driver, piston-feed option)	95
Grinding motor and blade assembly	60
Aluminum mold (custom machined / CNC)	120
Heating film / heating plate	25
DHT11 temperature and humidity sensor	4
Switching power supply / desktop adapter	65
Funnel, outlet tube, fasteners and miscellaneous mechanical parts	35
3D printed parts	60
Reserved / contingency cost	80
Total cost	644

IV. Schedule

Table 7: Schedule for Each Group Member

Week	Jingyang Chen	Wenkai Zheng	Zixi Zhao	Zekai Song
2/24	Participate in group discussion and help define the overall project framework	Participate in group discussion and help define the electrical control direction	Participate in group discussion and propose the initial mechanical concept	Participate in group discussion and propose the initial structural concept
3/3	Research basic circuit requirements and controller options	Research power supply requirements and electrical interfaces	Research the overall working process and mechanical feasibility	Research the overall working process and structural feasibility
3/10	Determine preliminary electrical architecture and key control modules	Determine preliminary power and sensor connection scheme	Start preliminary mechanical design and subsystem division	Start preliminary structural design and subsystem division
3/17	Learn PCB design software and begin schematic preparation	Learn PCB design software and begin circuit planning	Build initial CAD model of the structure	Refine initial CAD model and mechanical layout
3/24	Practice soldering and continue schematic learning	Practice soldering and continue PCB tool learning	Continue CAD modeling and prepare prototype structure	Continue CAD modeling and support prototype preparation
3/31	Join the team presentation to report the preliminary scheme to the advisor	Join the team presentation to report the preliminary scheme to the advisor	Present the preliminary mechanical design and model scheme	Present the preliminary structural design and model scheme
4/7	Refine schematic design and study PCB layout based on the current scheme	Refine circuit connections and component placement based on the current scheme	Optimize the CAD model and mechanical details	Improve the demo model and evaluate assembly feasibility
4/14	Start PCB layout and confirm key electrical components	Start circuit simulation and improve the power/control design	Revise the mechanical model according to integration needs	Revise the structural model and prepare for fabrication
4/21	Complete the first version of integrated PCB/schematic	Test basic electrical functions and module connections	Build the main mechanical prototype	Assemble the structural prototype and support integration
4/28	Debug the electrical system and improve reliability	Debug sensor, control, and power modules	Test the mechanical structure and feeding assembly	Optimize model assembly and support full prototype testing
5/5	Verify circuit and control functions against requirements	Verify electrical safety and subsystem performance	Verify mechanical stability and model operation	Assist overall prototype testing and result collection
5/12	Final presentation preparation	Final presentation preparation	Final presentation preparation	Final presentation preparation

V. Ethics and Safety

5.1 Ethics

The Pet Feed Manufacturing Machine is designed to process ground raw material into shaped pet food products through feeding, molding, and low-temperature drying. As such, the design must follow a code of ethics and give priority to safety, honesty, and responsible engineering practice [4].

A primary ethical concern of this project is food-related contamination. Since the machine is intended for pet-feed production, all material-contact parts should be designed to reduce contamination from residue, loose fasteners, degraded prototype parts, or unclean surfaces. At the current stage, this system should be treated as a prototype for process validation rather than a fully food-grade manufacturing device. Therefore, claims regarding product safety, drying quality, and final performance must be based on actual testing rather than assumptions. This is especially important because the current design is still under refinement in terms of structural layout, PCB arrangement, and subsystem integration.

Another ethical issue is responsible process selection. During the design discussion, the team considered multiple heating approaches, including oil-bath heating and water-bath heating, and finally decided to adopt an extrusion/injection-style molding process followed by tray baking and drying. This choice is ethically justified because the oil-bath solution may introduce greater food-safety concerns, cleaning difficulty, and extra risk of oil contamination, while the current method is simpler, cleaner, and more suitable for controlled prototype testing. The team also decided to limit each batch to approximately 200–300 g, which helps avoid overproduction and makes the process easier to control.

Environmental responsibility is also considered in this design. The machine uses relatively low-temperature drying rather than excessive heating, which reduces unnecessary energy consumption and lowers the risk of thermal damage to the material. In addition, waste generated during prototyping, including failed batches, damaged electronic components, and disposable printed parts, should be minimized and handled properly. Overall, the team is committed to developing a safe, responsible, and practical prototype system for pet food processing [4], [6].

5.2 Safety

The major safety risks of this project come from the blade mechanism, the feeding and molding structure, the heating subsystem, and the electrical control system. Therefore, safety protection must be considered throughout both the mechanical and electrical design.

The blade area presents the most direct mechanical hazard. To prevent accidental hand contact during operation, the team plans to use a plastic barrier or plastic cover to isolate the blade from the user. This protective structure will prevent hands from directly entering the cutting region while still allowing material to pass through the designed path. This decision is consistent with general machine-guarding principles, since moving and rotating parts should be physically blocked to reduce injury risk [5].

The heating subsystem also introduces an important safety concern. Since the final process route uses molded material followed by baking/drying rather than oil-bath heating, the main thermal hazards are hot surfaces, heat transfer to nearby components, and accidental burns during handling. To address this, the heating section should include thermal insulation around the outside of the heating region so that users are not directly exposed to high-temperature surfaces. Temperature limits and heating duration should also be controlled through the electrical system to prevent overheating. These measures not only reduce burn risk, but also improve thermal stability during drying.

The feeding and molding structure may also create pinch points or pressure buildup if the material is too wet or if clogging occurs in the outlet or mold. For this reason, the feed rate and motor speed should be limited to keep the process stable, and the structure around the feeding path should prevent direct hand access during operation. Since the current design objective includes stable material flow and avoidance of clogging, these safety measures are directly related to both safe operation and system performance.

Finally, the electrical subsystem must be arranged so that wires, heating elements, and control components do not create additional hazards. Electronic components should be placed away from the hot zone and moving mechanical parts, and exposed wiring should be insulated as much as possible. The design should also include basic protective measures such as controlled power delivery, emergency shutdown capability, and safe maintenance procedures.

Maintenance or cleaning should only be performed after the system is powered off and the heating section has

cooled sufficiently. In summary, the use of blade shielding, heating insulation, guarded feeding paths, and protected electrical layout makes the machine safer and more suitable for prototype testing [5], [7].

VI. References

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